NREL

Interoffice Memorandum

National Renewable Energy Laboratory

TO: C. Wyman, N. Strawn

FROM: N. Hinman, Biofuels Program Manager

DATE: February 19, 1993

SUBJECT: MSW-GIS Report

The subject report is attached for C. Wyman as a document valuable for strategic planning.

The subject report is attached for N. Strawn to be added to the BIC.

File: BF/20.Gen Mgmt Memos/memo only

B02367 3471
Biofuels Information Center

National Renewable Energy Laboratory

TO: See list

FROM: K. Shaine Tyson

DATE: February 4, 1993

SUBJECT: MSW-GIS report review

Here is the somewhat overdue MSW-GIS report that we have been working on for OPA. Please note that there are still two maps missing: Map 6 and Map 13. They are not critical to the review process. Map 13 may need to be eliminated as it requires us to geocode 40,000 landfills. It will take several weeks to finish this. The other map got pulled due to a technical error that will be easy to fix.

There are only 22 pages of text, plus tables and maps. I am especially interested in your response to the material from page 10 onward. The first section deals primarily with a review of previous MSW-combustion and MSW-ethanol analyses. I hope you find this information helpful in the review process if you are short of time.

It would be great if you could get any comments back to me as soon as possible, since this work is already overdue; however, your comments are important and if you need the time please let me know and I will accommodate you.

cc: Bim Gupta
Phil Shepherd
~~Cindy Riley~~ Norm Hinman
Walter Short
Carol Riordan
Susan Anson

MUNICIPAL SOLID WASTE EVALUATION: A GEOGRAPHIC INFORMATION SYSTEM MINISTUDY

DRAFT

February 4, 1993

Technology and Resource Assessment Branch
Analytic Studies Division
National Renewable Energy Laboratory
Golden Colorado 80401

MSW-GIS Mini-Study
Phase II

Introduction

The traditional role of analytical support for OPA can be strengthened by the addition of a new tool for spatial analysis--Geographic Information Systems (GIS). This report summarizes how GIS expands and improves upon renewable energy technology analysis in many areas--resource availability, industrial expansion, projected capacity, and resource competition. The subject area chosen for this analysis is municipal solid waste (MSW) resources and two of the many renewable energy technologies capable of utilizing this resource--ethanol production using the cellulosic fraction of MSW and electricity generation using MSW.

MSW-electric generation is a commercial technology. According to the EPA there are Currently there are 182 MSW combustion facilities; the majority of which produce either electricity or steam while the remainder incinerate MSW as a waste disposal technology. Producing ethanol from cellulosic feedstocks is experimental at this time; however, there are two industrial firms working with NREL to bring this technology to commercial readiness in the near future. The cellulosic fraction of MSW--including paper, some types of packing, cardboard, yard wastes, and urban wood residue--has been proposed as a potential feedstock for initial facilities. One joint research agreement focuses exclusively on this application.

The MSW resource was selected for this study because it is an immediately available renewable energy resource and society has a strong desire to find an acceptable use for it to avoid mounting disposal costs and future environmental problems. This social need has manifested itself in attractive tipping fees which have been considered as incentives for renewable technology development--incentives that could offset the costs of developing risky or costly business ventures in renewable energy generation. This paper explores three issues where GIS can expand traditional analysis:

1) Expand the body of knowledge concerning regional resource characteristics

2) Explore the relationship between the location of renewable energy resources and industrial growth projections for renewable energy technologies

3) Examine the impact of local incentives and barriers that can influence future locations of renewable energy developments

In addition to these issues, GIS enhanced analysis opens up the possibility of performing regional analysis that can fortify national projections of renewable energy penetration rates, competitive advantages, environmental impacts, infrastructure requirements, and

many other issues that analysts have long been aware of but unable to cost-effectively examined without the appropriate tools.

The purpose of this work is to demonstrate how GIS improves and expands traditional analysis. This effort has resulted in valuable insights affecting the development potential of selected renewable energy technologies. While the results from this work are intended to help the sector offices identify areas where future research could benefit programs, this study is not a substitute for indepth analysis of important issues affecting municipal solid waste markets or the development of renewable energy technologies.

The paper has several parts, a description of the methodology and results of traditional analysis, a description of the GIS modeling activities, and a summary which provides recommendations for future analysis that has been made possible by this limited study. A discussion of traditional analysis is provided to provide the reader with a perspective on how resource analysis and renewable energy projections are currently performed. From this background the differences in GIS-enhanced analysis are evident.

Traditional analysis

The traditional approach to MSW resource assessment and projections of the future contributions and costs of technologies using MSW feedstocks is demonstrated in recent DOE and NREL publications. Selected sections in the National Energy Strategy (NES)[1], the NES Technical Annex 2[2], and the supporting technical paper by Randall Curlee[3] summarize the current DOE outlook on MSW-electric generation growth and its attendant issues. The NES, and its Annex 2, also summarize DOE's outlook concerning biomass-ethanol technology development and contributions. Recent papers and reports prepared by NREL have also stressed the advantages of MSW feedstocks for ethanol production.[4][5][6] Program documents describe potential resources available for biomass

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[1] DOE. 1991. *National Energy Strategy, First Edition 1991/1992*. Government Printing Office. DOE/S-0082P.

[2] DOE. 1991. *National Energy Strategy Technical Annex 2. Integrated Analysis Supporting the National Energy Strategy: Methodology, Assumptions and Results*. Government Printing Office. DOE/S-0086P.

[3] Curlee, T. Randall. 1992. *The Potential for Energy from the Combustion of Municipal Solid Waste*. Journal of Environmental Systems, Vol. 20, No. 4.

[4] *Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline, Volume I: Summary Report, Volume II: Appendices. Draft, October 1992*. National Renewable Energy Laboratory.

[5] Bergeron, Paul W. and Cynthia J. Riley. 1990. *Wastepaper as a Feedstock for Ethanol Production*. National Renewable Energy Laboratory.

ethanol, gasification, and electricity. The "White Paper" also presented consensus projections for both MSW-electric and cellulosic ethanol.[7]

Most projections of MSW rely on reports prepared by Franklin Associates Ltd. for the Environmental Protection Agency (EPA)[8]. Franklin Associates have provided estimates on the quantity, volume, and types of municipal solid wastes generated, recycled, combusted, and sent to landfills in the United States. There are other site-specific studies on MSW generation or composition which provide wide ranges of estimates; due to their site specific nature they are not generally appropriate for a national level study[9].

Franklin Associates Ltd.

According to the most recent Franklin reports, the U.S. generated 195 million tons of municipal solid waste in 1990; 162 million tons were ultimately disposed of in landfills, 31.9 million tons were combusted, and the remainder was recycled or composted. MSW generation is expected to increase to more than 222 million tons per year by 2000; of which, only 46.2 million tons are expected to be combusted. Recycling is projected to increase from 17 percent today to 25 percent by 1995.

Frankin Associates' estimates of gross MSW generation are based on product-flow analysis. Forecasts of GNP (Gross National Product); specifically, forecasts of the amounts of goods and services produced in the U.S. economy are multiplied by a waste factor associated with each category of goods and services. As a result of this particular methodology, these waste estimates are national in scope; they do not reflect regional characteristics such as climate, seasons, purchasing patterns, education, income, wealth, etc. The 1992 estimates include imported goods that had been omitted in previous estimates.

The Franklin reports also contain estimates of the amount of MSW diverted from the waste stream to recovery, composting, and combustion uses. The combustion estimates were based on actual operating rates, where available information existed; otherwise, they assumed that existing facilities operated at 80 percent of rated capacity. Forecasted

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[6] Lynd, Lee R. et al. 1991. *Fuel Ethanol from Cellulosic Biomass*. Science Magazine.

[7] *The Potential of Renewable Energy, An Interlaboratory White Paper*. SERI, March 1990.

[8] EPA. 1992. Characterization of Municipal Solid Waste in the United States: 1992 Update. EPA/530-R-92-019.

[9] Marin County [California] Report, 1977; New York State Solid Waste Management Plan, 1991; Monterey Park, CA Source Reduction and Recycling Element, 1991; Metropolitan Solid Waste Management Plan, Metropolitan Planning Commission, Kansas City Region, 1971; Town of Babylon, New York, Solid Waste Management Plan, 1991; and Gershman, Brickner, & Bratton, Inc, 1992 Draft, Construction Waste and Demolition Debris Recycling... A primer.

combustion is based on reports of new facilities under construction, proposed, planned, or approved. It is difficult to determine how the estimates of recovery (analogous but not equal to recycling) and composting were arrived at. From the discussion, it seems likely that they are based on industrial reports, trade association publications, and other various sources. Recovery and recycling are not synonymous because some wastes are generated during the recycling processes that are not accounted for. Wastes from recycling processes are classified as industrial wastes and are not included in estimates of municipal wastes. Therefore, we will assume that recovery and recycling are equal in this report.

The MSW stream examined by Franklin is a fraction, albeit a major fraction, of the material that is disposed in landfills (Figure 1). Subtitle D wastes (Subtitle D of the Resource Conservation and Recovery Act) deals with wastes other than hazardous wastes. It has been common practice to dispose of non-hazardous industrial wastes, municipal sludge, automobile salvage wastes, and construction and demolition wastes along with MSW in Subtitle D landfills. However, only MSW is covered in the Franklin Reports.

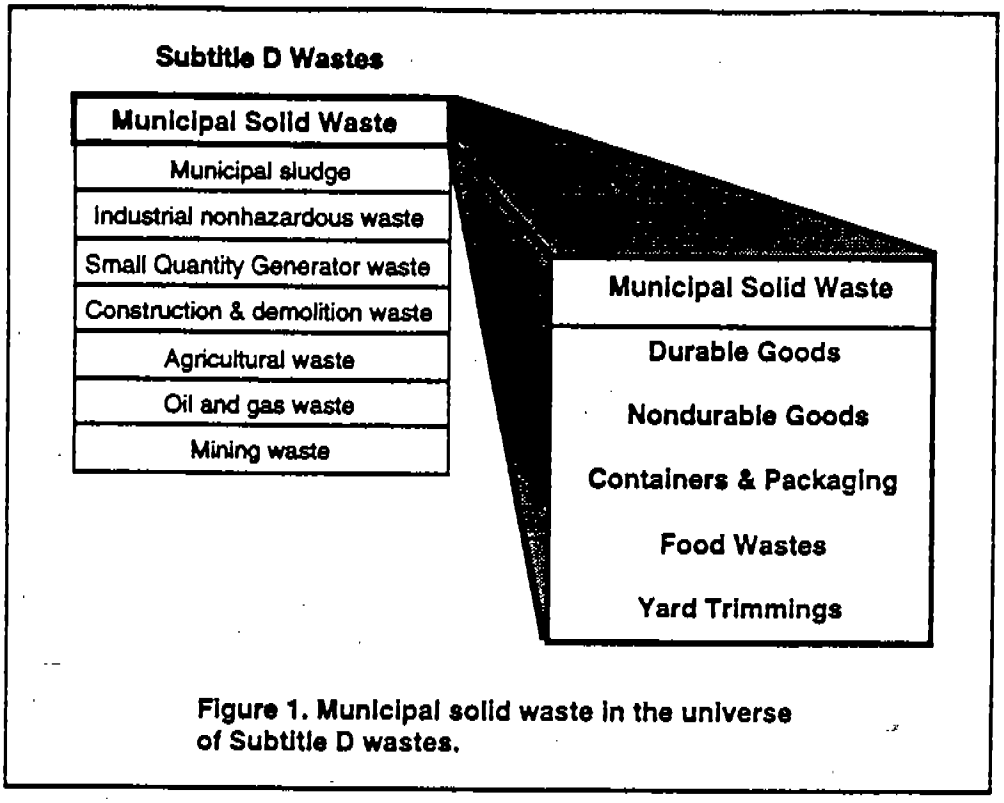

Figure 1. Municipal solid waste in the universe of Subtitle D wastes.

Figure 1.

NREL is searching for more information on the amount wastes suitable for combustion and ethanol that are not included in the Franklin reports, especially construction and demolition wastes, industrial wastes, and agricultural wastes. A draft consultant report prepared for the EPA describes the availability of construction and demolition wastes in the U.S. in general terms. Estimates provided in this report require peer review before they could be used for national studies. Other information is not currently available.

National Energy Strategy--MSW Power

As summarized in the NES, there are 160 waste to energy (WTE) plants in the U.S. today, producing 0.3 quads (4 gigawatts) of energy annually. This amount is projected to rise to 2.1 quads (28 gigawatts) by 2010 and to 4.1 quads (55 gigawatts) by 2030 (NES, 1990).

The reader should note that this energy estimate reflects the energy content of the MSW and is not an estimate of quads of end-use energy or capacity. To convert from raw tons of MSW to electricity, assume that one ton of MSW can produce 525 ($\pm$75) kWh with existing technology.

The National Energy Strategy points out that the political/regulatory environment does not currently favor MSW-combustion facilities. There is a high level of uncertainty concerning the health and ecological effects of air emissions and solid waste disposal. The NES proposes a number of polices that are intended to reduce the permitting time, make ash disposal easier, and generally promote the development of the MSW-electricity industry.

The NES assumes that the major part of the revenues for MSW facilities comes from tipping fees for waste disposal (in addition to the revenues from electricity generation), the future economics of this technology is region-specific. Furthermore, MSW usually competes primarily as a waste disposal alternative; it therefore it does not compete directly with other generating capacity. The projected growth in MSW-electric capacity is primarily driven by the increasing cost of other disposal opportunities (e.g. increasing tipping fees).

Municipal Waste Combustion Inventory (July 1992)

This recent report by Steve Levy (EPA) provides information on the number, type, location, and capacity of existing facilities (operational and nonoperational) as well as the planned facilities that are either in the conceptual stage (applied for permits, etc.), procurement stage or are under construction. This planned capacity is projected to be fully operational by 1995. In addition, this report provides information on energy recovery status; e.g., steam, steam/electric, electric, cogeneration, waste incineration, and RDF production.

According to this report there are 182 operating waste combusters in the United States, 147 of which recover energy. The 37 non-energy recovery facilities have a combined capacity of 6,219 tons per day; the capacity of the energy recovery facilities is 102,755

tons per day. The combined capacity of all of the waste generators is sufficient to handle 17.9 % of the municipal solid waste produced in 1991. Because they are generally larger, the energy recovery facilities account for 94 percent of the total installed combustion capacity. The operating energy recovery facilities have a combined capability to deliver more than 17 million megawatt-hrs of electricity per year (net energy).

Construction of new facilities has slowed recently; there are 9 new plants presently under construction. New, more stringent air emission regulations are likely to lead to the closure of a number of older (especially non-energy recovery) facilities. Procurement is underway on 84 additional projects. By 1995 combustion capacity could account for over 30 percent of the MSW generated in this country; an increase from 40 million tons MSW capacity per year today, to 87 million tons per year in 1995.

Potential for Energy from the Combustion of Municipal Solid Waste, 1991

T. Randall Curlee prepared the information that was used to support the MSW power projections in the NES. His projections for 5-year increments of time were grouped into three scenarios: low case, base case, and high case. The projections of MSW supply were based on population growth and growth of MSW generation per person over time.

The base case assumed that the per capita generation rate of MSW would remain constant from 2010 through 2030 at the mid-value estimate provided by Franklin Associates (1990)[10]. The low case assumed that the Franklin projections were too high; therefore generation estimates were reduced by 10 percent and 15 percent for 2000 and 2010, respectively. The generation rate was held constant thereafter. The high case assumed that MSW generation per capita would grow at its historical rate.

The composition of MSW was projected to change over time because recycling patterns affect the composition of MSW supplies. Curlee used the average heating value of MSW and created scenarios corresponding to his base case, high case and low case scenarios based on Franklin Associates projections. The Btus per pound of MSW fall over time in the low case, grow moderately in the base case, and grow substantially in the high case. These projections were only loosely patterned after Franklin Associates estimates of changing MSW composition over time.

Finally, Curlee also composed scenarios of future generation capacity as a fraction of *gross* MSW supply. By 2010, the MSW-combustion industry is projected to become static in all three cases, with 30 percent of gross MSW combusted in the low case scenario, 55 percent combusted in the base case, and 80 percent combusted in the high case.

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[10] EPA. 1990. Characterization of Municipal Solid Waste in the United States: 1990 Update. EPA/530-SW-90-042.

The resulting projections for Quads of energy are shown in Table 1. This table, originally titled: A Comparison with Other Projections of Energy *from* Combustion of MSW, is borrowed from Curlee's paper. Note however, that these quads represent energy *inputs* in the form of raw MSW, not energy *outputs*. Curlee's estimates are calculated from the estimates of *gross* MSW supply and not *net* supply which would be available to energy producers after recycling and composting. While Curlee discusses recycling activities, he did not include these in his estimates of energy projections. This method cannot be reconciled with his assumption that recycling will increase from 17 percent to 25 percent by 2000.

Table 1. MSW Combustion Estimates and Assumptions
Quads of Raw Feedstock Energy Combusted per year

	Curlee			SERI			
Year	Low Case	Base Case	High Case	Business as usual	R&D Scenario	Prem. Scenario	Klass
1990	0.26	0.29	0.32				
1995	0.42	0.64	0.70				
2000	0.50	0.95	1.22	0.20	0.26	0.34	0.60
2005	0.63	1.32	1.82				
2010	0.66	1.58	2.53	0.45	0.57	0.84	
2015	0.72	1.71	2.87				
2020	0.75	1.81	3.17	0.66	0.89	1.00	
2025	0.79	1.89	3.50				
2030	0.82	1.97	3.84	0.87	1.20	1.17	

SERI "White Paper" - MSW Combustion Estimates

The Interlaboratory White Paper on The Potential of Renewable Energy (1990) summarizes the consensus of renewable energy experts on the development and contributions of the renewable energy technologies under development by DOE. The MSW resource was estimated to be about 2 quads in 1990, expanding to 3 quads by 2030. The paper pointed out that the key issue is obtaining the lowest net cost of disposal of MSW. Thus projections were not necessarily a function of the price of energy, the need for energy, or the cost of energy produced.

The business-as-usual, R&D intensification, and the National Premiums scenarios were constructed to demonstrate how various government policies could affect renewable energy industrial development. The business-as-usual scenario assumes that government policy and R&D funding levels remain static over time at the 1989 level. Renewables are assumed to compete on the basis of end-use prices. The R&D intensification scenario assumes that cost reduction can be achieved by increasing the pace of R&D outlays, to make renewables competitive at an earlier date. The National Premiums scenario adds market incentives to the R&D scenario to create a more "level" playing field which include both "market pull" and "technology push" forces.

The consensus projections are compared to Curlee's projections in Table 1. The White paper also included projections by Klass (1988)[11]. Klass estimated that 90 percent of MSW is recoverable. Klass released an updated estimate in 1990[12] estimating that 0.60 quads of MSW combustion capacity could be achieved by 2000; a 50 percent increase over 1990 capacity.

National Energy Strategy--MSW-Ethanol

The NES does not explicitly discuss the potential of making ethanol from the cellulosic fraction of MSW. Projections on future capacity of ethanol-from-biomass technologies assume that a commercial facility is operating by 2003 (2005 with a less aggressive R&D program). The industry could have a capacity of 0.2 MMBD in 2010, increasing to 1.2 to 1.8 MMBD in 2030. Production costs were reported as $1.37 per gallon today, decreasing to $0.60 per gallon by 2000.

The NES support document: *Assessment of the Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector: Technical Report Twelve, Evaluation of Wood-to-Ethanol Process* is based entirely on a subcontractor's report delivered to NREL in 1990. This work is an independent evaluation of the NREL process; it is primarily a techno-economic feasibility analysis of converting poplar wood chips to ethanol. While the concept can be applied to MSW, no reports have been published to support estimated production costs for ethanol from MSW.

SERI "White Paper" - MSW Ethanol Estimates

The White paper does not mention ethanol produced from MSW at all. It concedes that earlier facilities will probably use by-product and waste materials from forest products and

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[11] Klass, Donald L. 1988. *The U.S. Biofuels Industry.* Proceedings of the International Renewable Energy Conference.

[12] Klass, Donald L. 1990. *The U.S. Biofuels Industry,* in Energy from Biomass and Wastes XIV, Institute of Gas Technology, Chicago, IL.

food processing industries. The focus of the White paper is on producing ethanol from energy crops.

Other studies - Ethanol

Appendix C of the *Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline* provides estimates of conversion efficiency and the technical feasibility of transforming the hemicellulosic fraction of MSW into ethanol. There is a high degree of uncertainty surrounding these estimates. Experiments at NREL and supporting firms have verified that selected materials found in MSW can be converted; however, actual samples of MSW containing contaminates and other matter have not be tested at this time. The yields of ethanol from selected components of MSW used in Appendix C have been applied to this MSW-GIS analysis. This study did not provide production cost information.

Appendix B of the *Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline* examines the processes required to acquire MSW, sort it, and deliver the RDF to an ethanol facility. This set of activities and the technology described are only one of many options, and this option may not reflect the industry mechanism that is widely adopted in 2000. This study indicated that a large population center (excess of 1 million people) may be required to support a 50 million gallon per day ethanol plant. This study indicated that the Chicago area could support such a facility.

Wastepaper as a Feedstock for Ethanol Production reviewed the wastepaper markets as a feedstock for ethanol plants. Wastepaper comprises a major fraction of MSW. The authors examined the wastepaper markets, including future wastepaper demand for deinking and pulp plants. Their conclusions were that between 1.36 and 2.4 billion gallons of ethanol could be produced from wastepaper, primarily from a category called mixed papers. The authors assumed that other categories of paper--old cardboard containers (OCC), computer paper, newspapers (ONP), etc.--would be in demand by pulp plants. The high demand will lead to relatively higher prices for the feedstock, placing ethanol facilities at a competitive disadvantage with pulp plants who can afford to offer substantially more. Only mixed papers are currently shunned by the market as pulp technologies have not been developed yet to utilize this resource.

This work also evaluated the economics of producing ethanol from paper. The authors examined two price levels--$10/ton and $25/ton. At either price level, ethanol produced from ONP and mixed papers compares favorably to wholesale gasoline prices, ranging from $0.50 to $0.67 per gallon. A 2,000 ton per day feedstock demand and a conversion ratio of 80 gallons per ton were assumed for both examples. Byproduct electricity sales produced substantial revenues in both cases.

Summary of Traditional Analysis

Traditional analysis has taken a national perspective in nearly every example cited; where MSW use for power production has received greater interest than MSW for ethanol

production. The common thread in all these analysis is that they start out examining the resource base by estimating it from common assumptions developed by Franklin Associates and the EPA. From this point they develop estimates of the quantity of the resource that could be used to supply power plants (ethanol plants are not clearly defined) based on various methods of extrapolating historical growth patterns into the future. Any differences in the resulting estimates of MSW-power potential lies in one of two areas: estimates of per capital MSW generation and estimates of potential resource that can be captured. The weakest parts of each analysis are the justifications of limits in the amount of resource that can be captured. Other than the absolute limits posed by the gross amounts of MSW generated there seems to be little rationale for maximum amount used for power generation. In addition, energy output costs, Kwh or gallon ethanol, are based on uniform assumptions or goals concerning feedstock costs and not on specific market conditions.

GIS-enhanced Analysis

As in traditional analysis, Franklin Associates provided a number of the basic assumptions used in this report (EPA, 1992 Update). Estimates of gross MSW generated, by type of waste, in 1990 and 2000 were divided by U.S. population estimates to arrive at estimates of categories of gross MSW generation per capita (Table 2). The Bureau of Census provided 1990 population estimates for the nation and per county from the 1990 Survey. Population was assumed to grow by 1 percent per year through the year 2000 for this study. Other projections of future population growth could have been used--for example, regional growth projections.

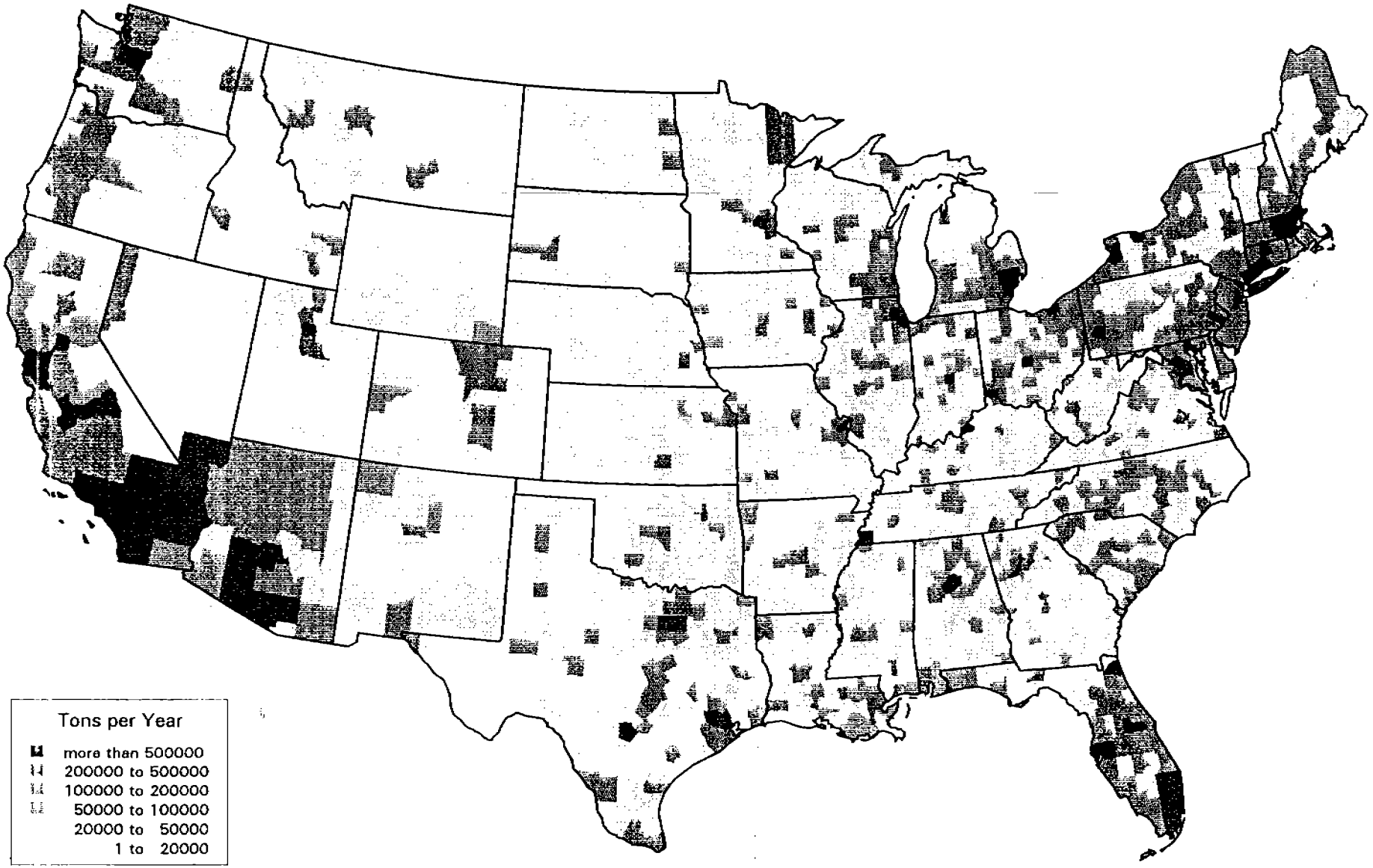
Regional distribution of MSW by county in shown in Map 1. Map 2 displays the same information based on population density (MSW per square mile). This particular estimate of population density is misleading because the area used in the denominator is county area, not necessarily the actual area through which the population is distributed. Also note, that since we used both county population and county area estimates, the scale changes but the information provided by both maps is identical. We will use Map 1 in the remainder of the analysis, although either map would have been acceptable.

These maps could have been generated on a state level, and were; however, the information shown on a county level provides a richer level of detail that showed specifically where resources were located. State-level analysis may show an entire state capable of generation a particular level of MSW when actually only a small area with high population density is responsible for 90 percent of the material generated. This is one of the benefits of GIS, a more detailed examination of resources locations and their surrounding infrastructure is possible. The regional information provided could be used to produce projections of MSW-combustion or ethanol development by state or region.

Table 2. Scenario data for 1990 with 17 percent recycling efficiency

Products	Generation Millions of wet tons	Percent of Generation	Percent recycling	Discards Millions of wet tons	Generation Wet ton per capita	Discards after recycling Wet ton per capita	Btu per capita raw content	kWh per capita	Ethanol (gal) per capita
Newspapers	12.9	6.6%	0.43	7.4	0.0518	0.0296	238.7	30.8	2.4
Books	1.0	0.5%	0.08	0.9	0.0039	0.0036	21.8	2.8	0.3
Magazines	2.8	1.4%	0.11	2.5	0.0113	0.0100	52.1	6.7	0.7
Office Papers	6.4	3.3%	0.27	4.7	0.0257	0.0188	114.0	14.7	1.6
Telephone Books	0.5	0.3%	0.07	0.5	0.0021	0.0020	16.1	2.1	0.2
Third Class Mail	3.8	2.0%	0.06	3.6	0.0153	0.0144	87.3	11.3	1.6
Other Commercial Printing	5.5	2.8%	0.19	4.5	0.0221	0.0180	109.2	14.1	2.0
Tissue Paper and Towels	3.2	1.6%	0.00	3.2	0.0127	0.0128	103.2	13.3	1.5
Paper Plates and Cups	0.7	0.3%	0.00	0.7	0.0026	0.0026	19.3	2.5	0.2
Plastic Plates and Cups	0.3	0.2%	0.07	0.3	0.0013	0.0012	21.4	2.8	0.0
Trash Bags	0.8	0.4%	0.00	0.8	0.0031	0.0032	24.7	3.2	0.0
Disposable Diapers	2.6	1.4%	0.02	2.6	0.0106	0.0104	26.0	3.4	0.0
Other Nonpackaging Paper	3.8	1.9%	0.00	3.8	0.0152	0.0152	92.2	11.9	0.0
Clothing and Footwear	3.7	1.9%	0.95	0.2	0.0150	0.0008	3.8	0.5	0.0
Towels, Sheets, & Pillowcases	1.0	0.5%	0.00	1.0	0.0039	0.0040	19.0	2.5	0.0
Other Misc. Nondurables	3.2	1.6%	0.00	3.2	0.0128	0.0128	0.0	0.0	0.0
Food Wastes	13.2	6.7%	0.00	13.2	0.0528	0.0528	87.8	11.3	0.6
Yard Trimmings	35.0	17.9%	0.12	30.8	0.1400	0.1232	204.9	26.4	1.3
Miscellaneous Inorganic Wastes	2.9	1.5%	0.00	2.9	0.0116	0.0116	0.0	0.0	0.0
Major Appliances	2.8	1.4%	0.02	2.8	0.0113	0.0111	0.0	0.0	0.0
Furniture and Furnishings	7.4	3.8%	0.00	7.4	0.0295	0.0296	35.2	4.5	0.0
Carpets and Rugs	1.7	0.9%	0.01	1.7	0.0068	0.0068	28.9	3.7	0.0
Rubber Tires	1.8	0.9%	0.02	1.8	0.0073	0.0072	52.8	6.8	0.0
Batteries, Lead-Acid	1.7	0.9%	0.00	1.7	0.0068	0.0068	0.0	0.0	0.0
Miscellaneous Durables	12.5	6.4%	0.00	12.5	0.0499	0.0500	0.0	0.0	0.0
Beer and Soft Drink Bottles	5.7	2.9%	0.33	3.8	0.0228	0.0152	0.0	0.0	0.0
Wine and Liquor Bottles	2.1	1.1%	0.09	1.9	0.0084	0.0076	0.0	0.0	0.0
Food and Other Bottles & Jars	4.1	2.1%	0.12	3.6	0.0165	0.0144	0.0	0.0	0.0
Steel Beverage Cans	0.1	0.1%	0.32	0.1	0.0006	0.0004	0.0	0.0	0.0
Steel Food and Other Cans	2.5	1.3%	0.25	1.9	0.0102	0.0076	0.0	0.0	0.0
Other Steel Packaging	0.2	0.1%	0.00	0.2	0.0008	0.0008	0.0	0.0	0.0
Aluminum Beverage Cans	1.6	0.8%	0.62	0.6	0.0063	0.0024	0.0	0.0	0.0
Aluminum Other Cans	0.0	0.0%	1.00	0.0	0.0001	0.0000	0.0	0.0	0.0
Aluminum Foil and Closures	0.3	0.2%	0.03	0.3	0.0012	0.0012	0.0	0.0	0.0
Corrugated Boxes	23.9	12.2%	0.48	12.5	0.0958	0.0500	353.2	45.5	5.2
Milk Cartons	0.5	0.3%	0.02	0.5	0.0020	0.0020	22.3	2.9	0.2
Folding Cartons	4.3	2.2%	0.07	4.0	0.0173	0.0160	117.6	15.2	1.4
Other Paperboard Packaging	0.3	0.1%	0.00	0.3	0.0011	0.0011	8.3	1.1	0.1
Bags and Sacks	2.4	1.2%	0.10	2.2	0.0097	0.0088	64.5	8.3	0.9
Wrapping Papers	0.1	0.1%	0.12	0.1	0.0005	0.0004	2.9	0.4	0.0
Other Paper Packaging	1.0	0.5%	0.01	1.0	0.0041	0.0040	29.3	3.8	0.4
Plastic Soft Drink Bottles	0.4	0.2%	0.31	0.3	0.0017	0.0012	21.4	2.8	0.0
Plastic Milk Bottles	0.4	0.2%	0.18	0.3	0.0015	0.0012	23.9	3.1	0.0
Other Plastic Containers	1.8	0.9%	0.01	1.8	0.0073	0.0072	143.6	18.5	0.0
Plastic Bags and Sacks	0.9	0.5%	0.04	0.9	0.0037	0.0036	71.8	9.3	0.0
Plastic Wraps	1.5	0.8%	0.02	1.5	0.0061	0.0060	119.6	15.4	0.0
Other Plastics Packaging	1.9	1.0%	0.00	1.9	0.0076	0.0076	151.5	19.5	0.0
Wood Packaging	7.9	4.0%	0.05	7.5	0.0316	0.0300	246.5	31.8	2.7
Other Misc. Packaging	0.2	0.1%	0.07	0.2	0.0009	0.0008	16.0	2.1	0.0
Total	195.732	100%	0.17	162.0	0.78	0.65	2750.9	354.7	23.4

Gross MSW Production per County
1990 Franklin Data



Total MSW = 194.774 Million Tons per Year

Because of the methodology used, areas with large population centers are also areas with high MSW concentrations. The assumption that MSW per capita correctly projects regional MSW distribution was tested; if inaccurate, the validity of the results of this study are suspect. There are many reasons why population may not be an accurate indication of regional MSW distribution. Different climates produce different levels of wood waste and lawn clippings. Different sections of the county produce different amount of newspapers, phone books, packaging and other types of wastes. Areas with high population growth due to birth rates may have more disposable diapers than others. Areas with low income may produce less MSW due to different spending patterns than areas with high incomes.

To test the accuracy of this assumption, we decided to display the regional distribution of net MSW generation and the locations of existing MSW combustion facilities. The EPA provided information on the type, capacity, and status of MSW combustion facilities operating, closed, and planned in the future (Table 3). If the locations of the MSW combustion facilities correspond closely with the concentration of MSW supplies, we could have faith that our assumptions were adequate for this study. Obviously, more site specific variables have an effect on the location of combustion facilities and the distribution of MSW, but if there is a high coincidence between the two we can assume that these differences probably do not affect the validity of the outcomes of this research.

Net generation is the production of MSW after recycling and composting has removed fractions from the waste stream (Map 3). What remains is the portion of MSW generated that has no other use than to landfill it or combust it. Franklin Associates's estimates of the composition and quantity of materials in the waste stream after recycling and composting for 1990 are used for net MSW available for combustion (Table 2).

The yellow points in Map 4 show where a MSW-combuster with a 500 tpd capacity could be located based on the available MSW supply. The red stars show were MSW combusters are operating today; the red triangles show where developers are planning to build new capacity. The sizes of the points and stars indicate relative capacity levels. A visual examination revealed that there was a high level of coincidence between the yellow points and red symbols. From this exercise we concluded that population is highly correlated with MSW supplies and population distribution can adequately projected where enough MSW is currently available to support existing and planned combustion facilities.

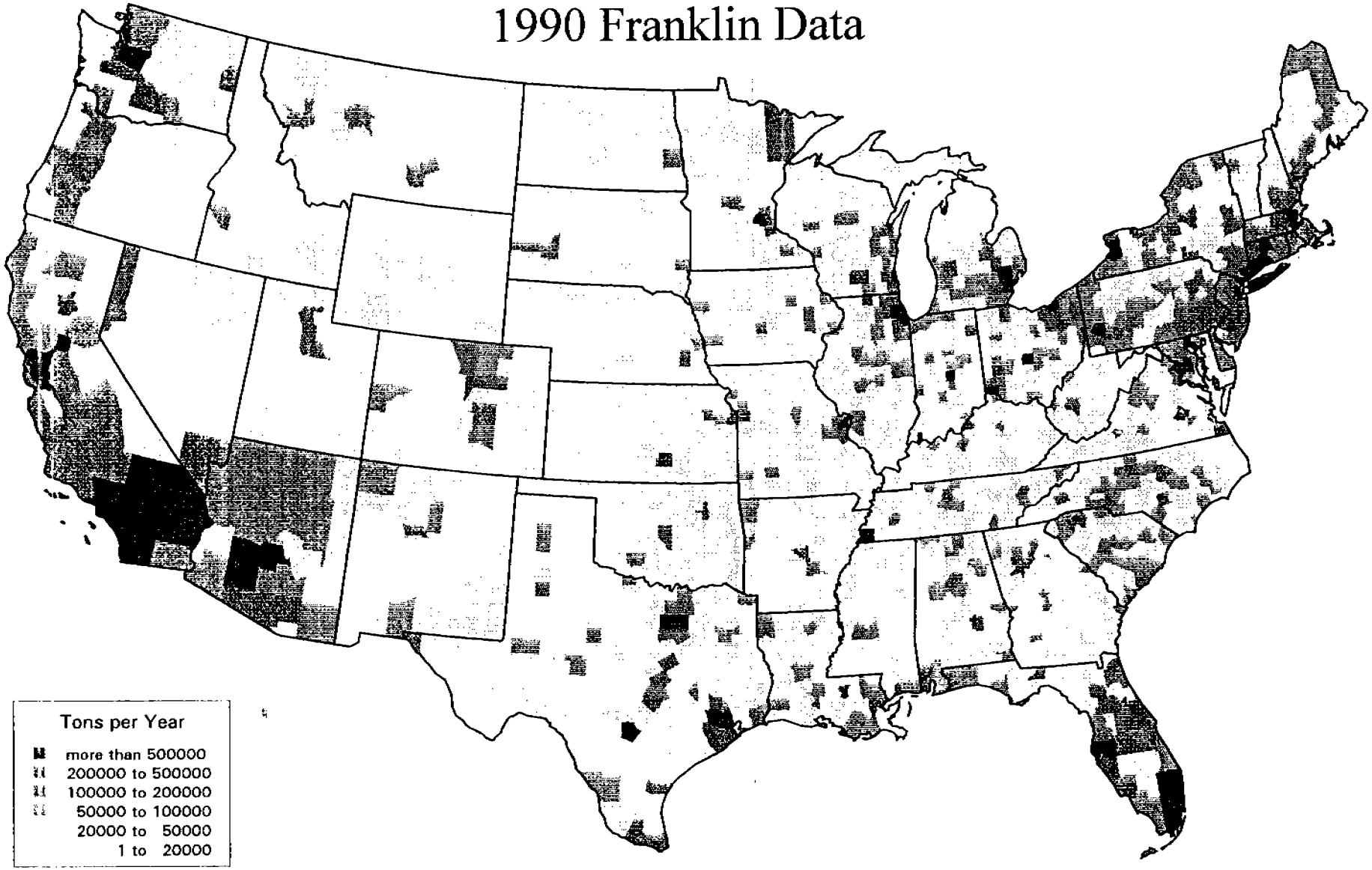
Maps 5 and 6 show the coincidence of county resources and the locations of existing facilities. The yellow points have been removed for simplicity. Note that most of the existing MSW combustion facilities are located in or near counties with large MSW supplies, according to population distribution.

If future analysis warrants, a proximity search could be undertaken which would relate the location of the possible sites (yellow points) and existing or planned sites (red stars or triangles). This type of search allocates MSW produced in a specific location to a specific

Table 3. Existing and Planned MSW Combustion Capacity

State	1990 MSW Combustion Facilities: Number of Operating Facilities	1990 MSW Combustion Facilities: Capacity of Operating Facilities	1990 MSW Combustion Facilities: Number of Planned Facilities	1990 MSW Combustion Facilities: Capacity of Planned Facilities	2000 MSW Combustion Facilities: Number of Operating Facilities	2000 MSW Combustion Facilities: Capacity of Operating Facilities
AK	3	71,175	2	5,475	5	76,650
AL	2	361,350	2	547,500	4	908,850
AR	5	138,700	2	109,500	7	248,200
AZ	0	0	1	547,500	1	547,500
CA	4	989,150	0	0	4	989,150
CO	0	0	2	164,250	2	164,250
CT	7	2,168,100	7	1,040,250	14	3,208,350
DC	1	91,250	0	0	1	91,250
DE	1	219,000	2	438,000	3	657,000
FL	14	6,367,790	6	3,394,500	20	9,762,290
GA	1	182,500	2	1,186,250	3	1,368,750
HI	1	788,400	0	0	1	788,400
IA	2	83,950	1	0	3	83,950
ID	1	18,250	0	0	1	18,250
IL	1	584,000	8	2,248,400	9	2,832,400
IN	2	1,025,650	1	109,500	3	1,135,150
KS	0	0	1	365,000	1	365,000
KY	1	182,500	2	233,600	3	416,100
LA	0	0	0	0	0	0
MA	9	3,723,000	9	1,796,530	18	5,519,530
MD	4	1,828,650	3	885,125	7	2,713,775
ME	6	810,665	2	255,500	8	1,066,165
MI	4	1,542,125	12	2,436,375	16	3,978,500
MN	15	2,511,930	3	357,700	18	2,869,630
MO	1	27,375	3	766,500	4	793,875
MS	1	54,750	0	0	1	54,750
MT	1	27,375	0	0	1	27,375
NC	4	281,780	5	857,750	9	1,139,530
ND	0	0	0	0	0	0
NE	0	0	0	0	0	0
NH	15	390,185	8	1,518,400	23	1,908,585
NJ	6	1,604,540	11	5,029,700	17	6,634,240
NM	0	0	0	0	0	0
NV	0	0	1	365,000	1	365,000
NY	17	4,825,665	23	8,207,025	40	13,032,690
OH	4	1,752,000	1	0	5	1,752,000
OK	2	450,045	1	299,300	3	749,345
OR	3	264,625	1	456,250	4	720,875
PA	5	2,190,730	19	5,635,965	24	7,826,695
RI	0	0	3	711,750	3	711,750
SC	2	333,610	1	1,095,000	3	1,428,610
SD	0	0	0	0	0	0
TN	5	594,950	3	620,500	8	1,215,450
TX	7	116,070	5	1,250,125	12	1,366,195
UT	1	146,000	1	164,250	2	310,250
VA	10	2,509,740	5	1,971,000	15	4,480,740
VT	2	8,395	1	27,375	3	35,770
WA	3	283,970	4	1,770,250	7	2,054,220
WI	9	731,460	3	465,375	12	1,196,835
WV	0	0	1	0	1	0
WY	0	0	0	0	0	0
Total	182	40,281,400	168	47,332,470	350	87,613,870

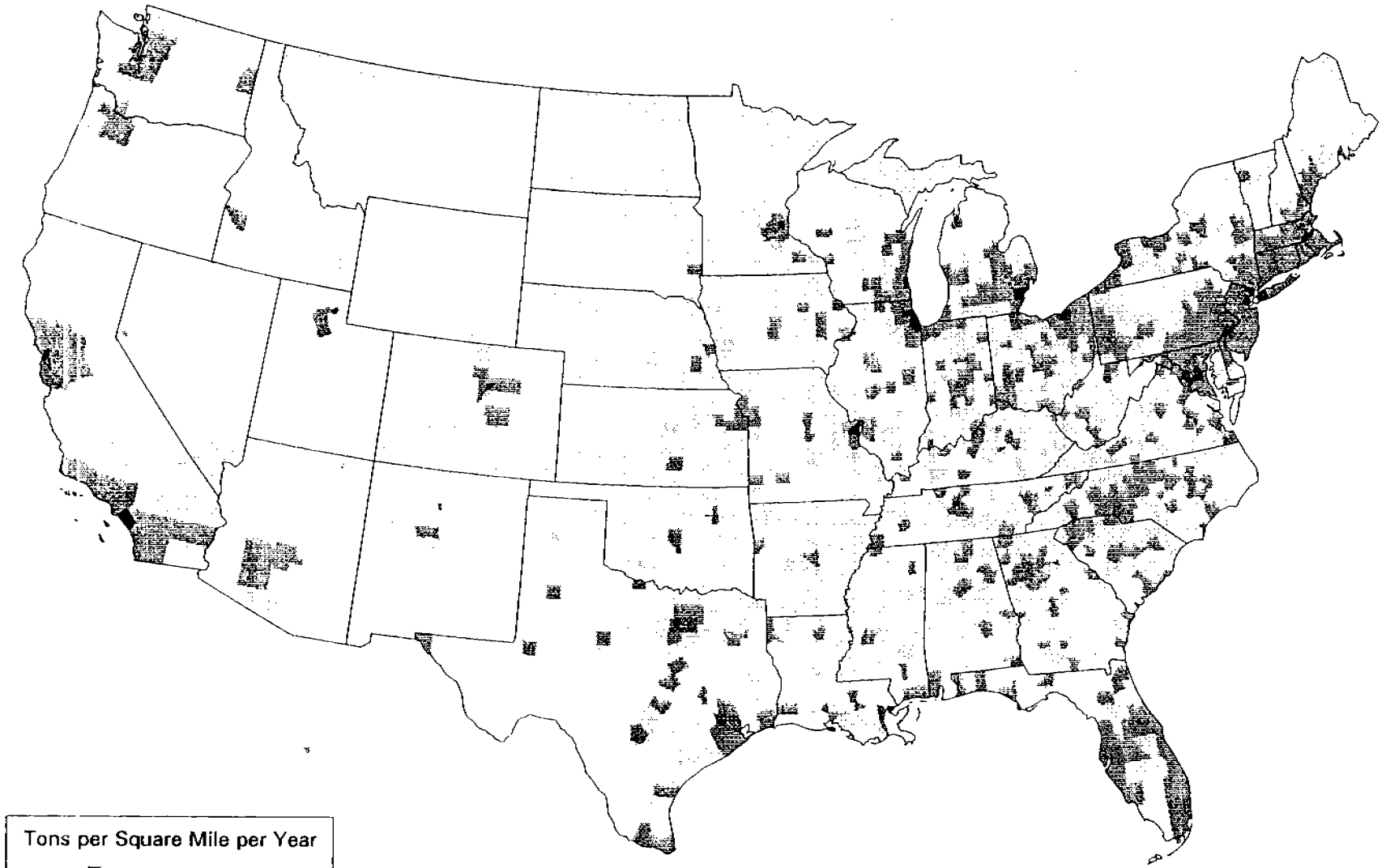
MSW Production per County
After Composting and Recycling
1990 Franklin Data



Total MSW = 161.281 Million Tons per Year

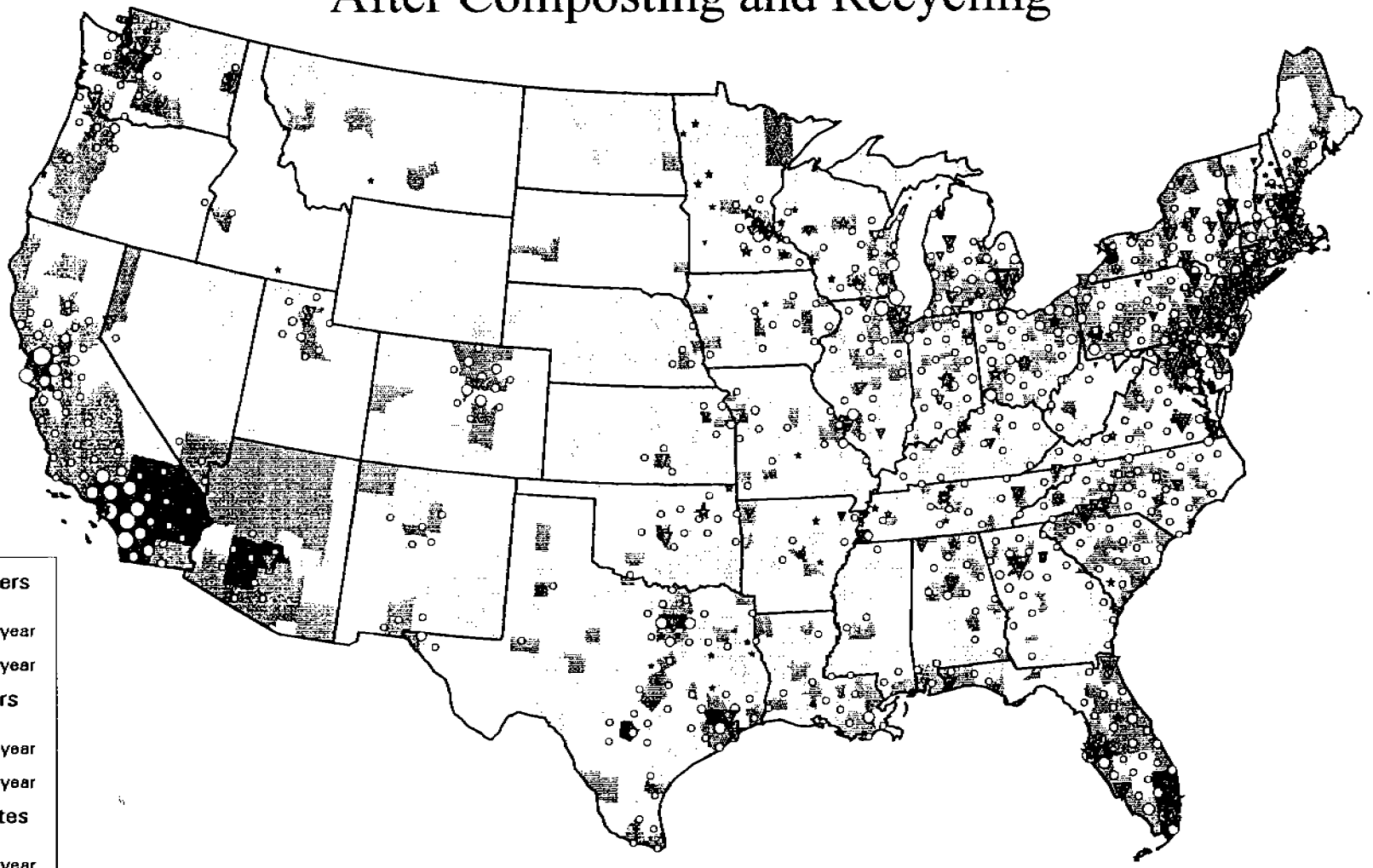
NREL Renewable Energy Resource Information & Analysis Center

MSW per Square Mile
1990 Franklin Data



NREL Renewable Energy Resource Information & Analysis Center

Existing and Proposed Combusters and New MSW-Electric Sites
1990 MSW Production per County
After Composting and Recycling



Operational Combusters

- ★ 2000000 tons per year
- • 1000 tons per year

Proposed Combusters

- ▼ 2000000 tons per year
- ▾ 1000 tons per year

New MSW-ElectricSites

- ◯ 7000000 tons per year
- ∘ 100000 tons per year

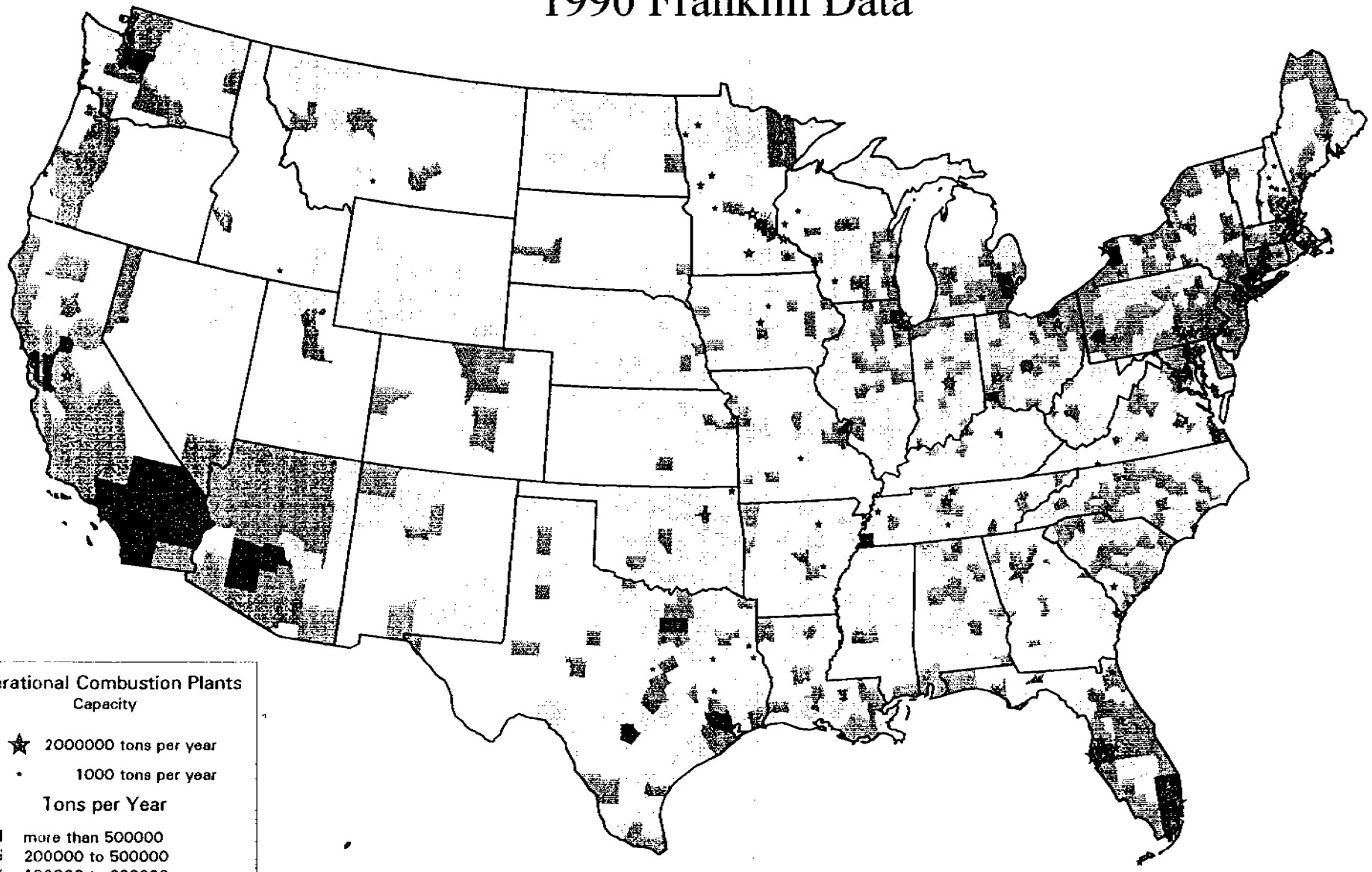
MSW Generation
Tons per Year

- ■ more than 500000
- ■ 200000 to 500000
- ■ 100000 to 200000
- ■ 50000 to 100000
- 20000 to 50000
- 1 to 20000

NREL Renewable Energy Resource Information & Analysis Center

Total Operational Capacity = 40.281 Million Tons per Year for 182 Plants
Total Proposed/Under Construction Capacity = 47.332 Million Tons per Year for 168 Plants
New Capacity = 164.870 Million Tons per Year for 580 Plants

MSW Production per County with Operational Combustion Plants
After Composting and Recycling
1990 Franklin Data



Total MSW = 161.281 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

consumption point. This detailed validation approach was not warranted for a national study; however, for a state or local a proximity search may yield important information.

MAPINFO, the mapping program used in this analysis to simulate GIS capabilities, cannot perform proximity analysis of a complex nature, such as when MSW from several nearby sources are used to support one centrally located combustion facility. This is one area where an advanced GIS could be beneficial. The potential sites (yellow points) were generated by performing a geographic search over the U.S. using MSW density as the database and assuming a 30 mile radius around the point. This geographic search was performed on a VAX mainframe because MAPINFO cannot support relational analysis. Therefore, a proximity search was not performed as part of this study.

One consideration that is important for developers, which we did not test, is the assumption that MSW composition remains constant across the nation. We recognize that this assumption is probably inaccurate. If further studies of MSW are undertaken, we recommend examining equations that dissaggregate the nation by climate, income, and other parameters that affect MSW composition. The problems likely to be encountered is the lack of data. There is very little information available on the types of wastes discarded by income, climate, industrial activities, and sociological factors. For this reason, this issue has not be resolved in this study and MSW composition is assumed to be fixed.

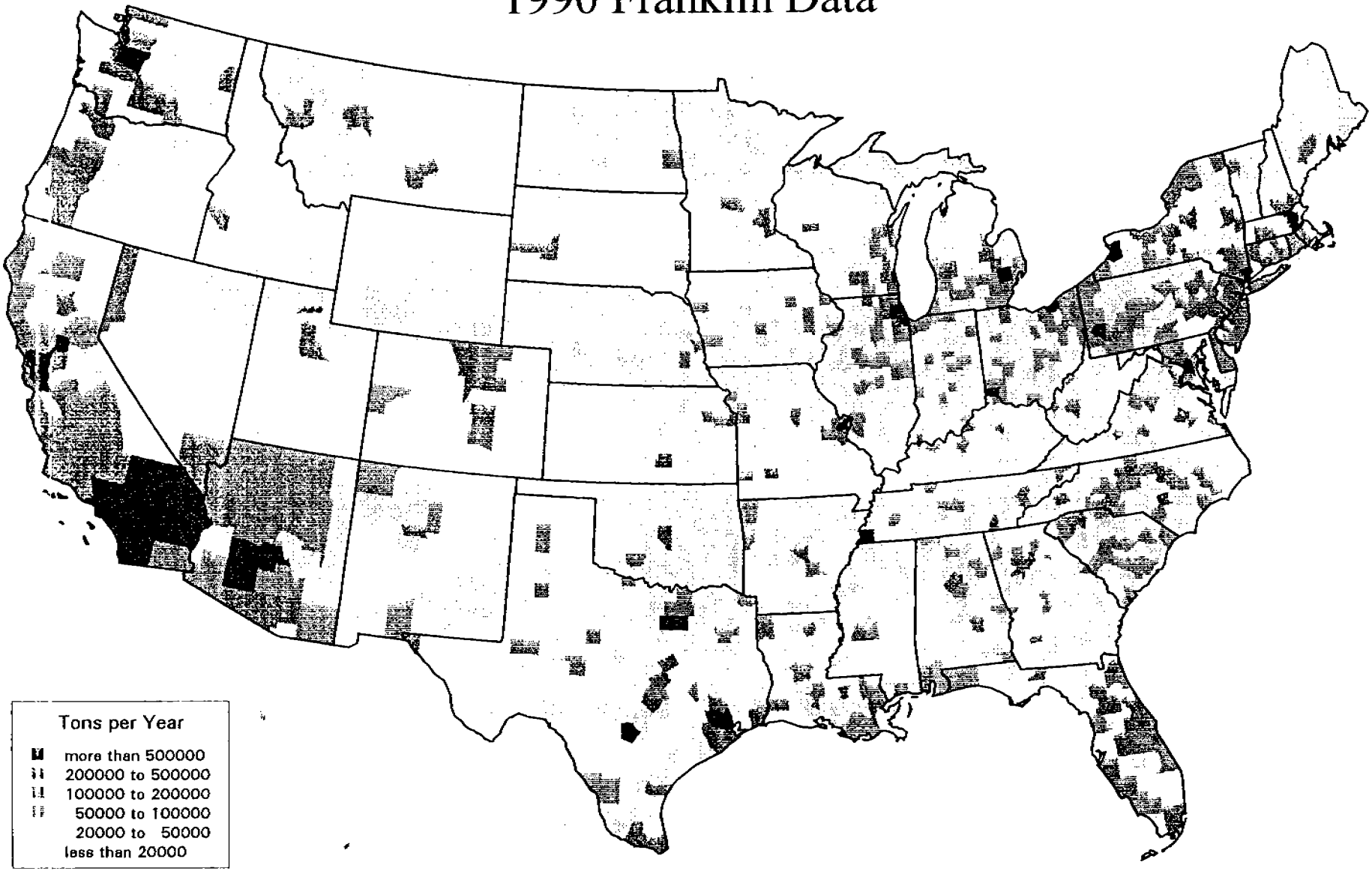
According to the results of Map 4, the U.S. has a capability of supporting a total of 580 facilities with a capacity of 500 tpd in 1990. In 1990 there were 182 MSW combustion facilities with a combined capacity of 40.28 million tons per year consuming roughly 32 million tons of MSW. There is an additional 168 facilities in the planning stages with a combined capacity of 47 million tons per year. For the purposes of this study, we assume that all 168 facilities in the planning stages are fully operational by 2000.

We assumed that all facilities operate at 80 percent capacity. This assumption is consistent with the assumption used in Franklin Associate's report (1992). Other DOE studies have assumed 70 percent (NES, 1991). This assumption can be altered by future analysts for sensitivity studies.

Note that most of the concentrated supplies of MSW in 1990 are regionally distributed; concentrating in California, Texas, and Northeastern states (Map 1 and 3). This type of information has value to analysts who are aware of incentives or barriers in these states that will affect future development of MSW electric or ethanol facilities. Some of these influences will be examined later.

In order to develop estimates of future capacity potential we developed maps to display the location and quantity of MSW available for future capacity--gross MSW net of composting, recycling, and operating combustion demand. The series of Maps 1, 3, and 7 show the differences between gross MSW, MSW net of recycling and composting, and

MSW Production per County
After Composting, Recycling, and Combustion
1990 Franklin Data



Total MSW = 129.127 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

MSW net of composting, recycling, and combustion for 1990. Maps 8, 9, 10, 11, and 12 show similar information for 2000. We assumed that recycling efficiency could reach 25 percent by the year 2000 (Map 9 and 10), an increase of only 6 percent from today's level. Maps 11 and 12 show the effects of 50 percent recycling efficiency, an extreme scenario. Other levels could be tested using the methodology developed here. The 2000 scenarios also assume that all combusters in the planning stages today are fully operational.

In order to generate MSW estimates by category of product that reflected the recycling efficiencies for 2000 we developed 2 scenarios shown in Tables 4 and 5. Franklin Associates had projections for recycling by broad categories of products for 25 percent efficiency, but none for 50 percent. Because we were using more detailed categories (to develop detailed Btu estimates of fuel value and ethanol conversion rates for use later in this analysis), we developed our own estimates of recycling efficiencies. We used Franklin Associates estimates of gross MSW generation by product category for 2000 and multiplied these values by various recycling efficiencies. The maximum recycling efficiency for any product was assumed to be 80 percent, except for lead-acid batteries which we assumed were removed from the municipal waste stream through regulation.

The 1990 map of MSW net of composting, recycling, and combustion show that the Northeast had excess MSW for future MSW-electric capacity or ethanol developments (Map 7). The 2000 map showing MSW with 25 percent recycling shows that the Northeast cannot support any new facilities, primarily because all of the MSW produced will be consumed by combustion facilities (Map 10). Anywhere the map is red, indicates that the **all** of the MSW produced in those regions is directed to one of the local MSW combustion plants. The MSW is presorted to some extent before combustion. The material that is not suitable for combustion and the ash from the plants are returned to local landfills.

Maps 10 and 12 indicate that the development of MSW combustion facilities currently listed in the planning stages have economic consequences for local landfill operators. Landfill operators require a minimum inflow of MSW to ensure a revenue stream adequate to cover fixed and operating expenses. If this material flow is diverted to combusters, and a smaller return flow ensues (of noncombustible products and ash), then many operators may be competing for reduced MSW supplies. In this competitive environment tipping fees could drop to very low levels. If the landfill operators are not only competing among themselves for MSW, but are also competing with MSW combusters, this will have an additional depressing effect on tipping fees.

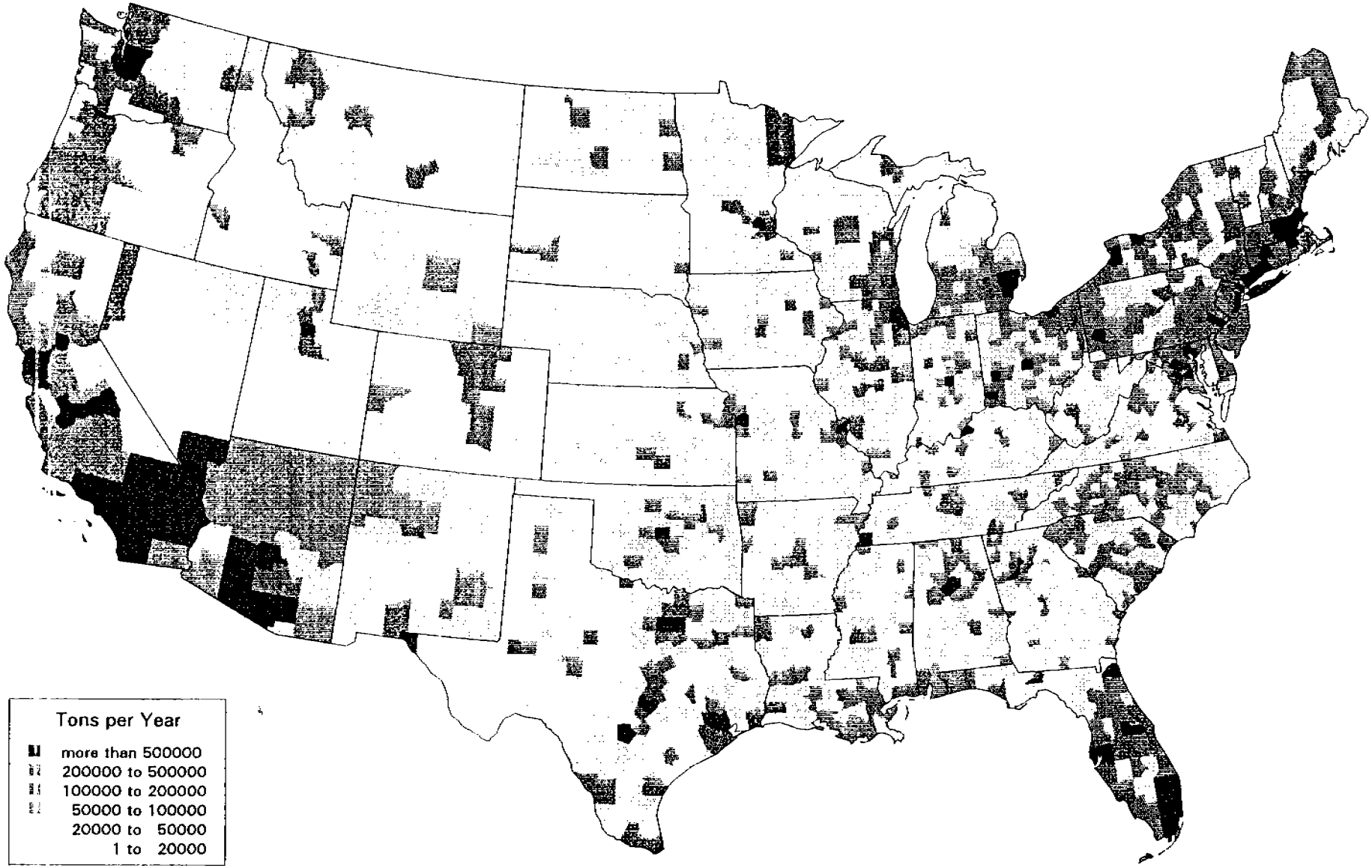
Table 4. Scenario data for 2000 with 25 percent recycling efficiency

Products	Generation Millions of wet tons	Percent of Generation	Percent recycling	Discards Millions of wet tons	Generation Wet ton per capita	Discards after recycling Wet ton per capita	Btu per capita raw content	kWh per capita	Ethanol (gal) per capita
Newspapers	15.1	6.8%	0.6	6.04	0.0547	0.0219	176.36	22.74	1.80
Books	1.2	0.5%	0.1	1.08	0.0043	0.0039	23.72	3.06	0.29
Magazines	3.8	1.7%	0.4	2.28	0.0138	0.0083	43.02	5.55	0.61
Office Papers	8.1	3.6%	0.5	4.03	0.0292	0.0146	88.52	11.41	1.24
Telephone Books	0.7	0.3%	0.5	0.33	0.0024	0.0012	9.64	1.24	0.10
Third Class Mail	4.6	2.0%	0.3	3.18	0.0165	0.0115	69.96	9.02	1.31
Other Commercial Printing	6.5	2.9%	0.4	3.90	0.0235	0.0141	85.66	11.04	1.60
Tissue Paper and Towels	3.8	1.7%	0	3.79	0.0137	0.0137	110.66	14.27	1.56
Paper Plates and Cups	0.7	0.3%	0	0.70	0.0025	0.0025	18.57	2.39	0.22
Plastic Plates and Cups	0.6	0.3%	0	0.56	0.0020	0.0020	36.10	4.65	0.00
Trash Bags	1.3	0.6%	0	1.34	0.0049	0.0049	37.40	4.82	0.00
Disposable Diapers	2.9	1.3%	0.1	2.62	0.0105	0.0095	23.70	3.06	0.00
Other Nonpackaging Paper	4.1	1.9%	0	4.13	0.0150	0.0150	90.71	11.69	0.00
Clothing and Footwear	4.5	2.0%	0	4.48	0.0162	0.0162	77.15	9.95	0.00
Towels, Sheets, & Pillowcases	1.2	0.5%	0	1.20	0.0043	0.0043	20.65	2.66	0.00
Other Misc. Nondurables	5.5	2.5%	0	5.46	0.0198	0.0198	0.00	0.00	0.00
Food Wastes	13.2	5.9%	0	13.20	0.0478	0.0478	79.49	10.25	0.52
Yard Trimmings	32.9	14.8%	0.3	23.03	0.1192	0.0834	138.68	17.88	0.90
Miscellaneous Inorganic Wastes	3.1	1.4%	0	3.10	0.0112	0.0112	0.00	0.00	0.00
Major Appliances	3.4	1.5%	0.05	3.19	0.0122	0.0116	0.00	0.00	0.00
Furniture and Furnishings	9.1	4.1%	0	9.11	0.0330	0.0330	39.17	5.05	0.00
Carpets and Rugs	2.8	1.3%	0	2.78	0.0101	0.0101	42.84	5.52	0.00
Rubber Tires	2.4	1.1%	0.1	2.15	0.0086	0.0078	56.98	7.35	0.00
Batteries, Lead-Acid	2.2	1.0%	0	2.24	0.0081	0.0081	0.00	0.00	0.00
Miscellaneous Durables	13.9	6.3%	0	13.88	0.0503	0.0503	0.00	0.00	0.00
Beer and Soft Drink Bottles	5.6	2.5%	0.5	2.78	0.0201	0.0101	0.00	0.00	0.00
Wine and Liquor Bottles	2.2	1.0%	0.2	1.78	0.0081	0.0065	0.00	0.00	0.00
Food and Other Bottles & Jars	4.1	1.9%	0.3	2.90	0.0150	0.0105	0.00	0.00	0.00
Steel Beer and Soft Drink Cans	0.1	0.1%	0.4	0.07	0.0004	0.0003	0.00	0.00	0.00
Steel Food and Other Cans	2.3	1.0%	0.3	1.59	0.0082	0.0058	0.00	0.00	0.00
Other Steel Packaging	0.2	0.1%	0	0.18	0.0007	0.0007	0.00	0.00	0.00
Aluminum Beer and Soft Drink C	2.0	0.9%	0.75	0.51	0.0073	0.0018	0.00	0.00	0.00
Aluminum Other Cans	0.1	0.0%	0.75	0.02	0.0003	0.0001	0.00	0.00	0.00
Aluminum Foil and Closures	0.4	0.2%	0.2	0.34	0.0015	0.0012	0.00	0.00	0.00
Corrugated Boxes	27.0	12.2%	0.7	8.10	0.0978	0.0293	207.21	26.71	3.04
Milk Cartons	0.5	0.2%	0.1	0.45	0.0018	0.0016	18.18	2.34	0.14
Folding Cartons	4.7	2.1%	0.1	4.23	0.0170	0.0153	112.59	14.52	1.31
Other Paperboard Packaging	0.3	0.1%	0.1	0.27	0.0011	0.0010	7.19	0.93	0.08
Bags and Sacks	2.5	1.1%	0.1	2.27	0.0091	0.0082	60.18	7.76	0.85
Wrapping Papers	0.1	0.1%	0.2	0.09	0.0004	0.0003	2.44	0.31	0.03
Other Paper Packaging	1.0	0.5%	0.1	0.93	0.0037	0.0034	24.72	3.19	0.36
Plastic Soft Drink Bottles	0.7	0.3%	0.5	0.34	0.0024	0.0012	21.67	2.79	0.00
Plastic Milk Bottles	0.5	0.2%	0.3	0.36	0.0019	0.0013	26.28	3.39	0.00
Other Plastic Containers	3.5	1.6%	0.1	3.11	0.0125	0.0113	224.84	28.99	0.00
Plastic Bags and Sacks	1.4	0.6%	0.1	1.26	0.0051	0.0046	90.97	11.73	0.00
Plastic Wraps	2.0	0.9%	0.1	1.80	0.0072	0.0065	129.96	16.75	0.00
Other Plastics Packaging	2.6	1.2%	0	2.60	0.0094	0.0094	187.73	24.20	0.00
Wood Packaging	10.6	4.8%	0.1	9.55	0.0384	0.0346	284.10	36.63	3.14
Other Misc. Packaging	0.2	0.1%	0.1	0.22	0.0009	0.0008	16.00	2.06	0.00
Total	222.087	100%	0.26	163.6	0.80	0.59	2683.02	345.89	19.12

Table 5. Scenario data for 2000 with 50 percent recycling efficiency

Products	Generation Millions of wet tons	Percent of Generation	Percent recycling	Discards Millions of wet tons	Generation Wet ton per capita	Discards after recycling Wet ton per capita	Btu per capita raw content	kWh per capita	Ethanol (gal) per capita
Newspapers	15.1	6.8%	0.8	3.02	0.0547	0.0109	88.18	11.37	0.90
Books	1.2	0.5%	0.3	0.84	0.0043	0.0030	18.45	2.38	0.23
Magazines	3.8	1.7%	0.7	1.14	0.0138	0.0041	21.51	2.77	0.31
Office Papers	8.1	3.6%	0.8	1.61	0.0292	0.0058	35.41	4.56	0.50
Telephone Books	0.7	0.3%	0.8	0.13	0.0024	0.0005	3.85	0.50	0.04
Third Class Mail	4.6	2.0%	0.5	2.28	0.0165	0.0082	49.97	6.44	0.94
Other Commercial Printing	6.5	2.9%	0.7	1.95	0.0235	0.0071	42.83	5.52	0.80
Tissue Paper and Towels	3.8	1.7%	0.1	3.41	0.0137	0.0124	99.59	12.84	1.40
Paper Plates and Cups	0.7	0.3%	0.1	0.63	0.0025	0.0023	16.71	2.15	0.20
Plastic Plates and Cups	0.6	0.3%	0.1	0.50	0.0020	0.0018	32.49	4.19	0.00
Trash Bags	1.3	0.6%	0	1.34	0.0049	0.0049	37.40	4.82	0.00
Disposable Diapers	2.9	1.3%	0.2	2.33	0.0105	0.0084	21.07	2.72	0.00
Other Nonpackaging Paper	4.1	1.9%	0.2	3.30	0.0150	0.0120	72.57	9.36	0.00
Clothing and Footwear	4.5	2.0%	0.05	4.26	0.0162	0.0154	73.29	9.45	0.00
Towels, Sheets, & Pillowcases	1.2	0.5%	0.05	1.14	0.0043	0.0041	19.61	2.53	0.00
Other Misc. Nondurables	5.5	2.5%	0.05	5.19	0.0198	0.0188	0.00	0.00	0.00
Food Wastes	13.2	5.9%	0.2	10.56	0.0478	0.0383	63.59	8.20	0.41
Yard Trimmings	32.9	14.8%	0.6	13.16	0.1192	0.0477	79.24	10.22	0.51
Miscellaneous Inorganic Wastes	3.1	1.4%	0.05	2.95	0.0112	0.0107	0.00	0.00	0.00
Major Appliances	3.4	1.5%	0.2	2.69	0.0122	0.0097	0.00	0.00	0.00
Furniture and Furnishings	9.1	4.1%	0.2	7.28	0.0330	0.0264	31.33	4.04	0.00
Carpets and Rugs	2.8	1.3%	0	2.78	0.0101	0.0101	42.84	5.52	0.00
Rubber Tires	2.4	1.1%	0.4	1.43	0.0086	0.0052	37.99	4.90	0.00
Batteries, Lead-Acid	2.2	1.0%	1	0.00	0.0081	0.0000	0.00	0.00	0.00
Miscellaneous Durables	13.9	6.3%	0.3	9.72	0.0503	0.0352	0.00	0.00	0.00
Beer and Soft Drink Bottles	5.6	2.5%	0.8	1.11	0.0201	0.0040	0.00	0.00	0.00
Wine and Liquor Bottles	2.2	1.0%	0.7	0.67	0.0081	0.0024	0.00	0.00	0.00
Food and Other Bottles & Jars	4.1	1.9%	0.7	1.24	0.0150	0.0045	0.00	0.00	0.00
Steel Beer and Soft Drink Cans	0.1	0.1%	0.6	0.05	0.0004	0.0002	0.00	0.00	0.00
Steel Food and Other Cans	2.3	1.0%	0.6	0.91	0.0082	0.0033	0.00	0.00	0.00
Other Steel Packaging	0.2	0.1%	0.2	0.14	0.0007	0.0005	0.00	0.00	0.00
Aluminum Beer and Soft Drink C	2.0	0.9%	0.8	0.40	0.0073	0.0015	0.00	0.00	0.00
Aluminum Other Cans	0.1	0.0%	0.8	0.01	0.0003	0.0001	0.00	0.00	0.00
Aluminum Foil and Closures	0.4	0.2%	0.3	0.30	0.0015	0.0011	0.00	0.00	0.00
Corrugated Boxes	27.0	12.2%	0.8	5.40	0.0978	0.0196	138.14	17.81	2.03
Milk Cartons	0.5	0.2%	0.4	0.30	0.0018	0.0011	12.12	1.56	0.09
Folding Cartons	4.7	2.1%	0.2	3.76	0.0170	0.0136	100.08	12.90	1.17
Other Paperboard Packaging	0.3	0.1%	0.3	0.21	0.0011	0.0008	5.59	0.72	0.07
Bags and Sacks	2.5	1.1%	0.5	1.26	0.0091	0.0046	33.43	4.31	0.47
Wrapping Papers	0.1	0.1%	0.5	0.06	0.0004	0.0002	1.53	0.20	0.02
Other Paper Packaging	1.0	0.5%	0.5	0.52	0.0037	0.0019	13.73	1.77	0.20
Plastic Soft Drink Bottles	0.7	0.3%	0.8	0.13	0.0024	0.0005	8.67	1.12	0.00
Plastic Milk Bottles	0.5	0.2%	0.8	0.10	0.0019	0.0004	7.51	0.97	0.00
Other Plastic Containers	3.5	1.6%	0.5	1.73	0.0125	0.0063	124.91	16.10	0.00
Plastic Bags and Sacks	1.4	0.6%	0.3	0.98	0.0051	0.0035	70.76	9.12	0.00
Plastic Wraps	2.0	0.9%	0.2	1.60	0.0072	0.0058	115.52	14.89	0.00
Other Plastics Packaging	2.6	1.2%	0.2	2.08	0.0094	0.0075	150.18	19.36	0.00
Wood Packaging	10.6	4.8%	0.7	3.18	0.0384	0.0115	94.70	12.21	1.05
Other Misc. Packaging	0.2	0.1%	0.3	0.17	0.0009	0.0006	12.44	1.60	0.00
Total	222.087	100%	0.50	110.0	0.80	0.40	1777.25	229.12	11.33

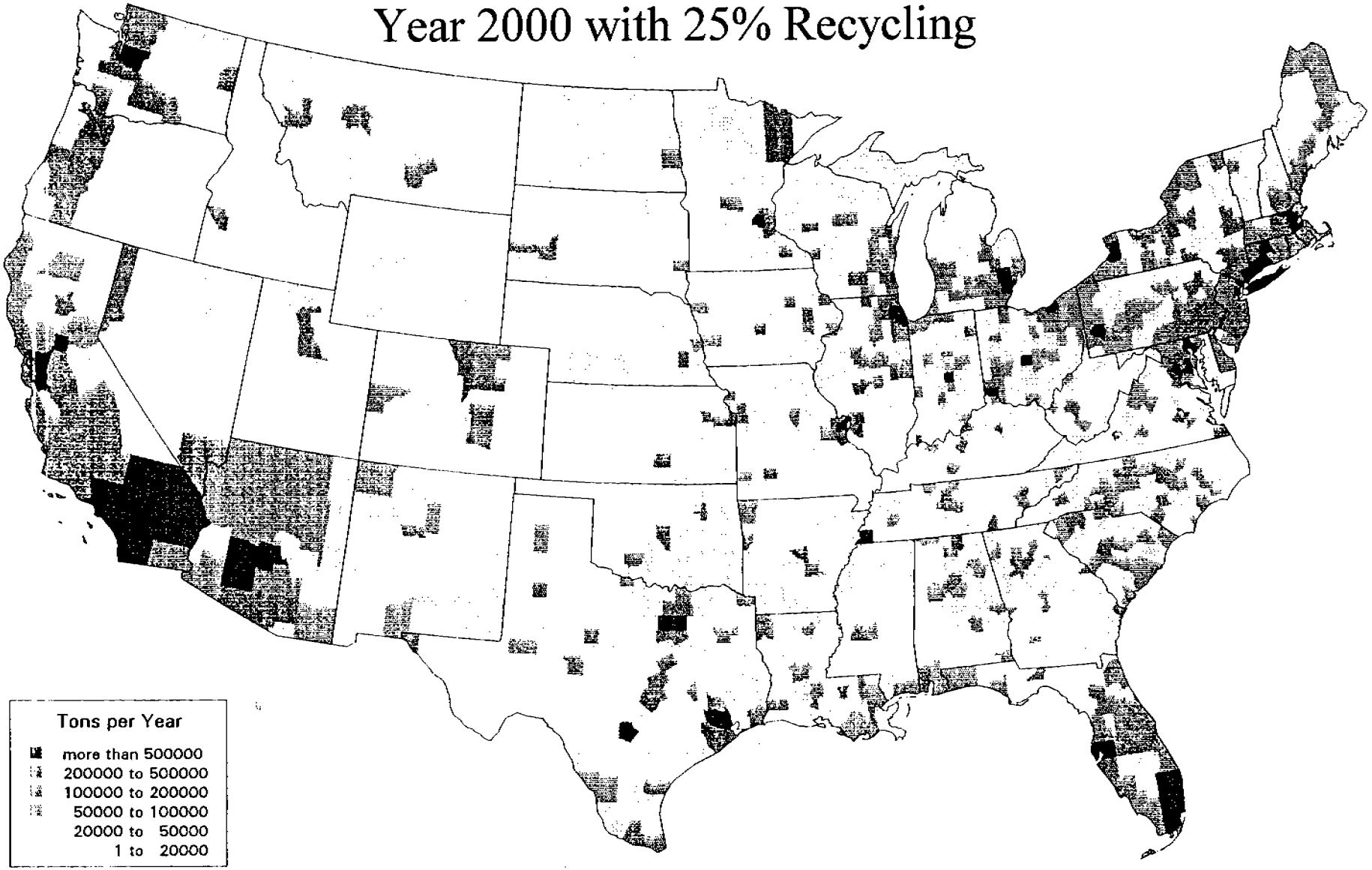
Gross MSW Production per County
Year 2000, Franklin Estimate



Total MSW = 220.997 Million Tons per Year

NREL Renewable Energy Resource Information & Analysis Center

MSW Production per County
After Composting and Recycling
Year 2000 with 25% Recycling



Total MSW = 162.752 Million Tons per Year

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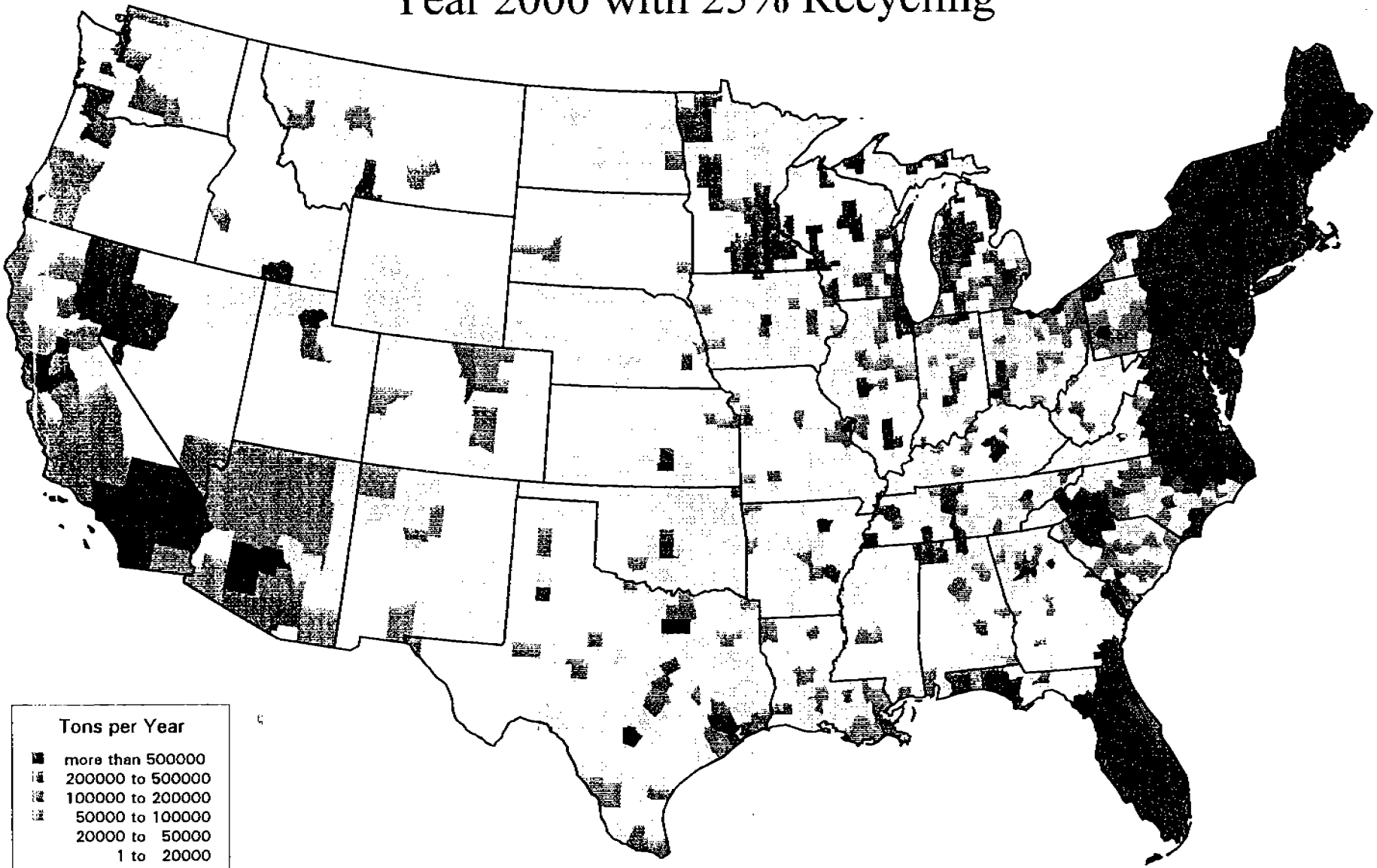
MSW Production per County
After Composting, Recycling, and Combustion
Year 2000 with 25% Recycling



Total MSW = 92.676 Million Tons per Year

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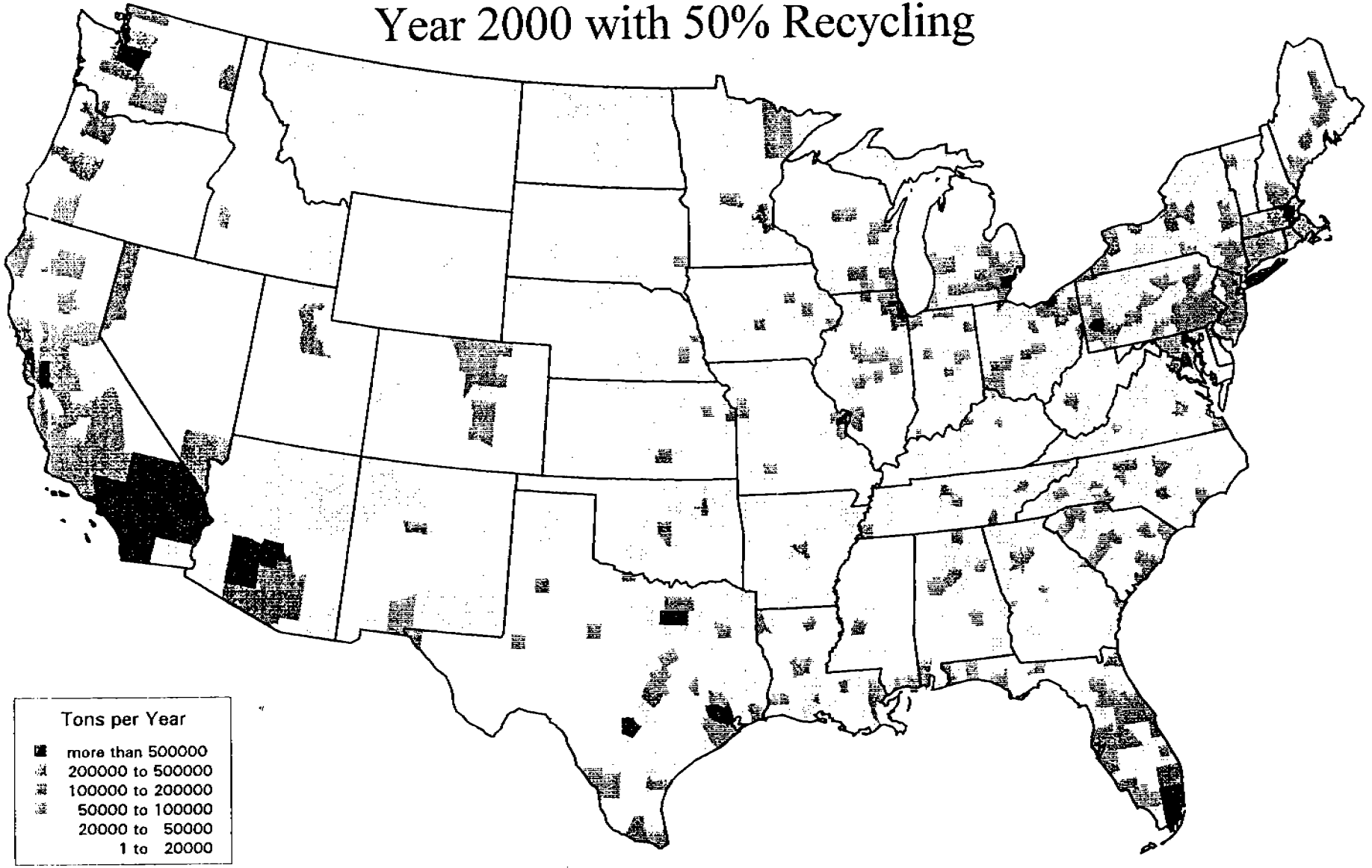
MSW Production per County
After Composting and Recycling
Year 2000 with 50% Recycling



Total MSW = 109.426 Million Tons per Year

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Recent discussions between NREL project managers working with the Eastern municipal waste industry and waste industry operators have revealed that the MSW industry is subject to the same competitive influences that other industries experience. The recent recession and continuing slow economic growth have affected consumers spending patterns; these consumers have been purchasing less and producing less MSW. The drop in local MSW supplies have caused landfill operators to reduce their tipping fees in an effort to compete for a shrinking pool of MSW. These dynamics support our projection that intense competition for MSW will cause tipping fees to fall.

If both tipping fees and MSW flows to landfills decline, many landfill operators could become bankrupt. The red counties shown in Map 13 show that projected MSW combustion demand, for just the facilities that exist today or are planned today, have implications for the landfill operators located there (green squares). Both bankruptcy and the changing composition of materials sent to landfills could have environmental consequences. Landfill operators faced with declining revenue streams could reduce environmental control costs (such as liner thickness or fill), accept illegal wastes, or fail to invest in equipment and tests required after landfill closure. These environmental consequences should be considered in the framework of MSW combustion fuel cycle analysis.

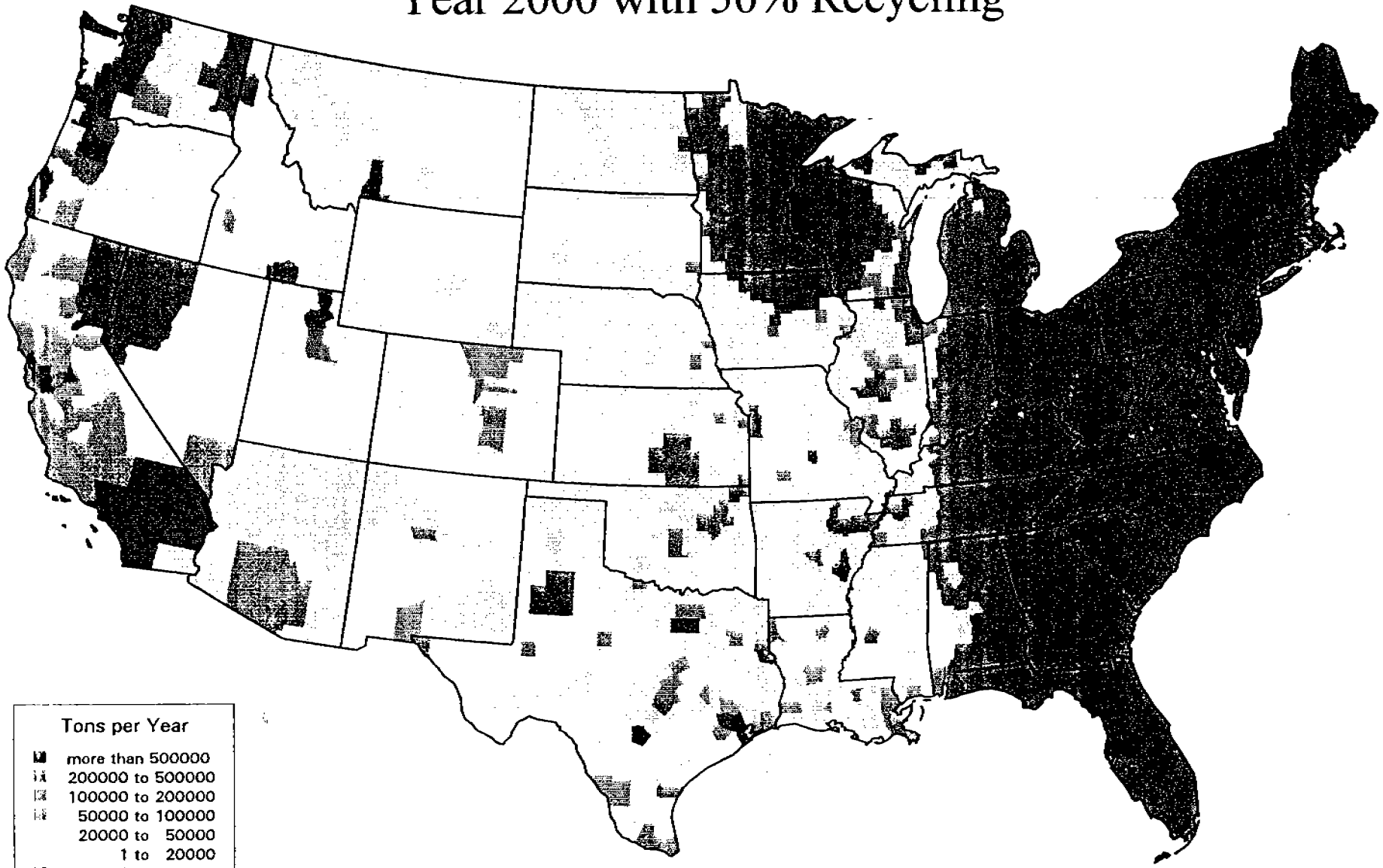
Depressed tipping fees and MSW supplies also have implications for future energy developments using MSW feedstocks. Tipping fees are attractive incentives for energy developers, providing a secondary revenue stream to augment energy sales; thereby subsidizing the costs of producing energy. If tipping fees fall, the cost of the energy produced increases. Transportation costs will also rise if local supplies of MSW decline and MSW needs to be transported longer distances.

If MSW power is sold under contracts tied to local avoided costs, there is a limited opportunity to pass along any increase in cost to the utility or grid. These cost increases may be borne by the investors. The decline in financial stability faced by existing operators may dampen industrial development.

The market for MSW is difficult to characterize. There are many contract mechanisms borne by the municipalities, private MSW collectors, government agencies, and landfill operators and combusters. The effect of changes in tipping fees will depend on the structure of the contracts and negotiations, and are highly site specific. In this study we do not attempt to estimate the change in tipping fees, only recognize the underlying factors that could bring about this change. We merely caution readers that future analyses need to be tempered by a detailed examination of these types of impacts.

Abstracting from the economic issues, we returned to the process of examining how much MSW is physically available (not ecomically viable) and use these estimates to develop projections about future capacity growth. Using the information provided in Maps 7, 10, and 12 (MSW net of composting, recycling, and combustion for 1990 and 2000,

MSW Production per County
After Composting, Recycling, and Combustion
Year 2000 with 50% Recycling



Total MSW = 39.351 Million Tons per Year

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respectively) we developed estimates of where MSW electric and ethanol facilities can be located using information provided in Tables 2, 4 and 5.

In 1990 an MSW-ethanol facility required 4,160 tpd to produce 50 million gallons of ethanol. According to NREL Biofuel researchers, a 50 million tpd facility is a minimum size based on the economies of scale in ethanol conversion. Larger facilities could reduce the average cost of ethanol produced. By 2000, an ethanol plant needed 4,650 tpd to operate in the 25 percent recycling efficiency scenario, increasing to 5,280 tpd in the 50 percent scenario. The organic fractions of MSW decline over time since currently commercial recycling activities target the organic fractions of MSW--such as paper, wood, and yard waste--and plastics recycling lags. MSW combustion facilities were not as affected, since the changing composition of MSW slightly increased the Btu content of the material because a higher fraction of plastics remain in the waste stream (Table 6). Therefore, the size of the MSW facilities remained constant at 500 tpd.

Table 6. Energy values per ton of raw MSW

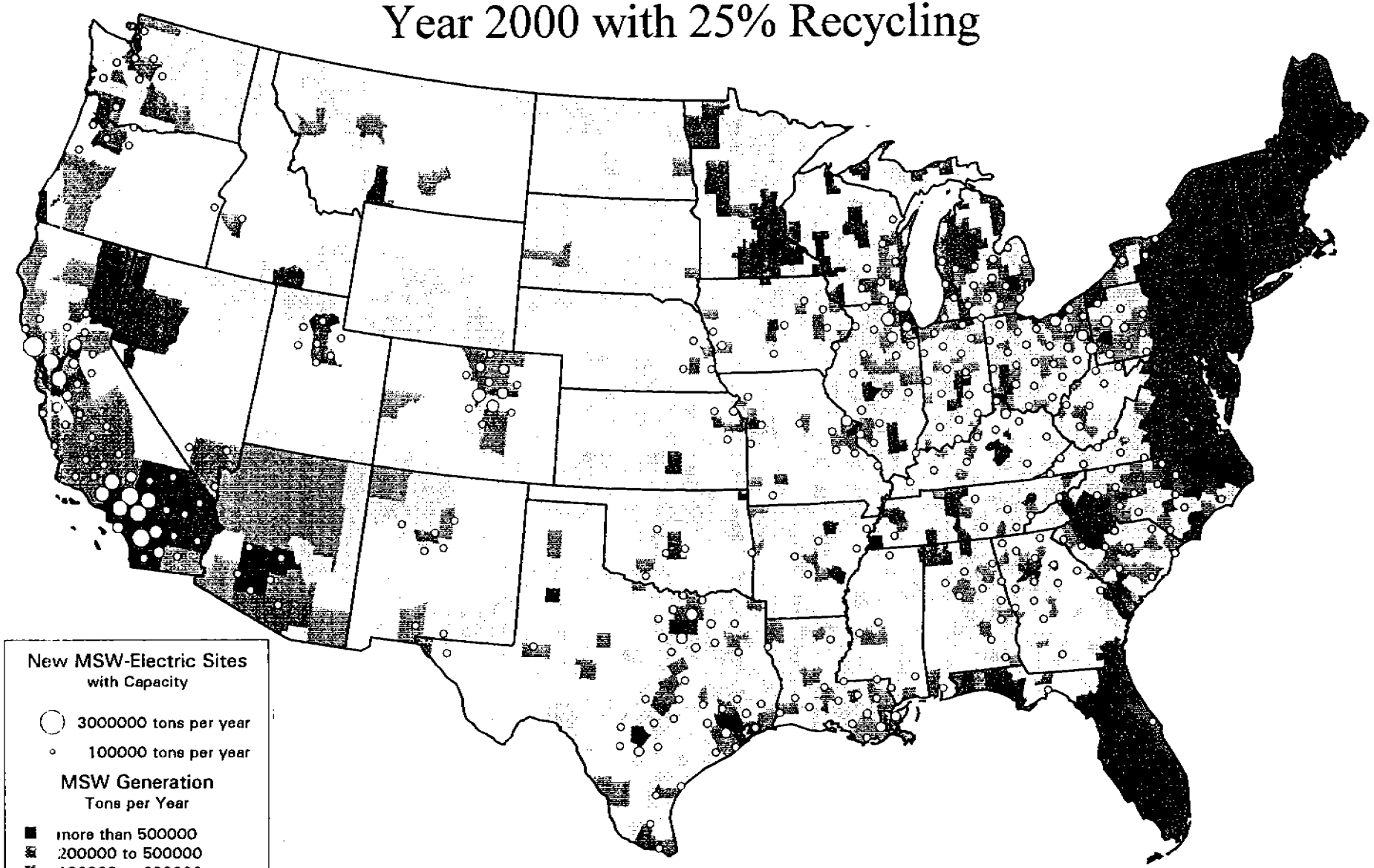
Scenario	Btu/ton*	kWh/ton*	gallon/ton*
1990	4244	547	36
2000 25% recycling	4528	584	32
2000 50% recycling	4462	575	28

*tons referred to in Table 6 are wet tons as received at plant gate, unsorted.

The number of potential new facilities that could be supported by MSW supplies which are not dedicated to other uses (recycling, composting and combustion) declines over time because of increases in recycling efficiency and the impact of combustion capacity in the planning stages today (Table 7). This information is displayed geographically in Maps 14 through 18.

Part of the reason that the number of sites decline between 1990 and 2000 is the impact made by MSW combustion facilities in the planning stages today. All 168 of these facilities (total capacity of 47 million tons MSW) are assumed to be operational by 2000. The total existing MSW-electric capacity in 2000 is 87.5 million tons per year, with another 79 million tons possible if recycling rates remain low and only 34 million tons additional capacity if recycling rates are high. Cautious investor's may chose to site facilities only where they could be viable under either condition, which could constrain industrial growth to the lower of the two values.

MSW Production per County with New MSW-Electric Sites After Composting, Recycling, and Combustion Year 2000 with 25% Recycling



Total New Capacity = 79.035 Million Tons per Year for 364 Plants

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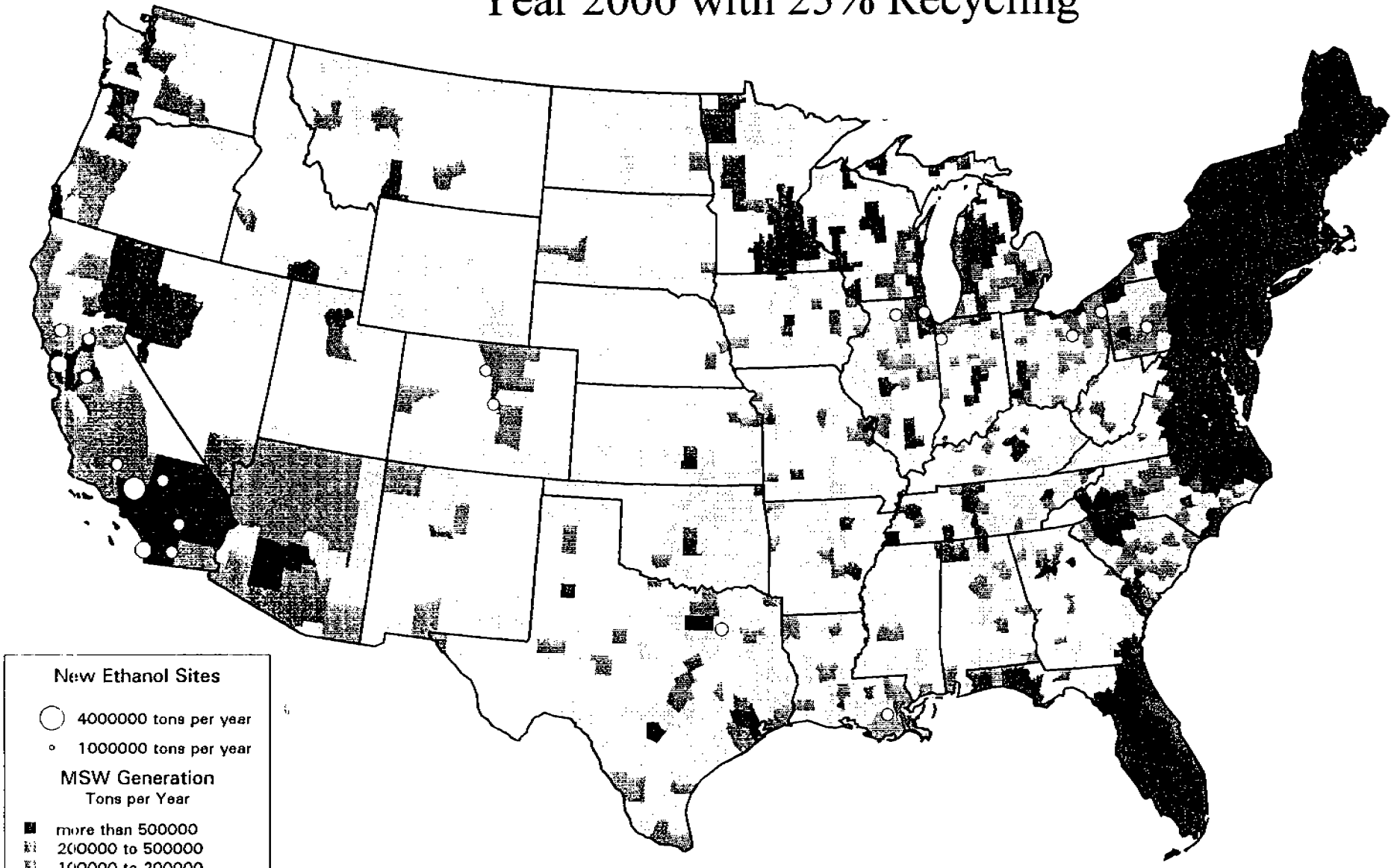
MSW Production per County with New Ethanol Sites After Composting, Recycling, and Combustion Year 2000 with 25% Recycling



Total New Capacity = 34.845 Million Tons per Year for 20 Plants

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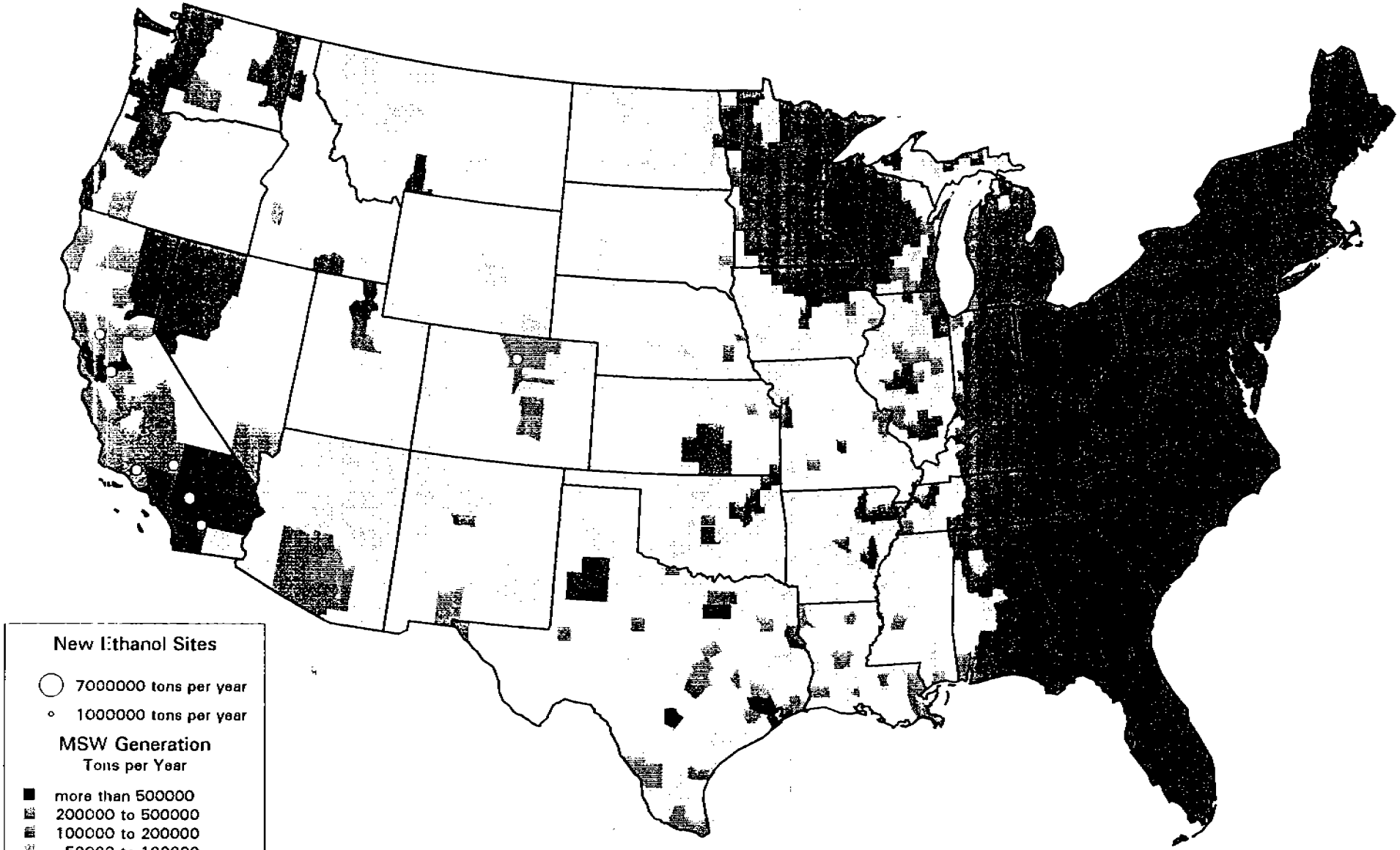
MSW Production per State with New Ethanol Sites After Composting, Recycling, and Combustion Year 2000 with 50% Recycling



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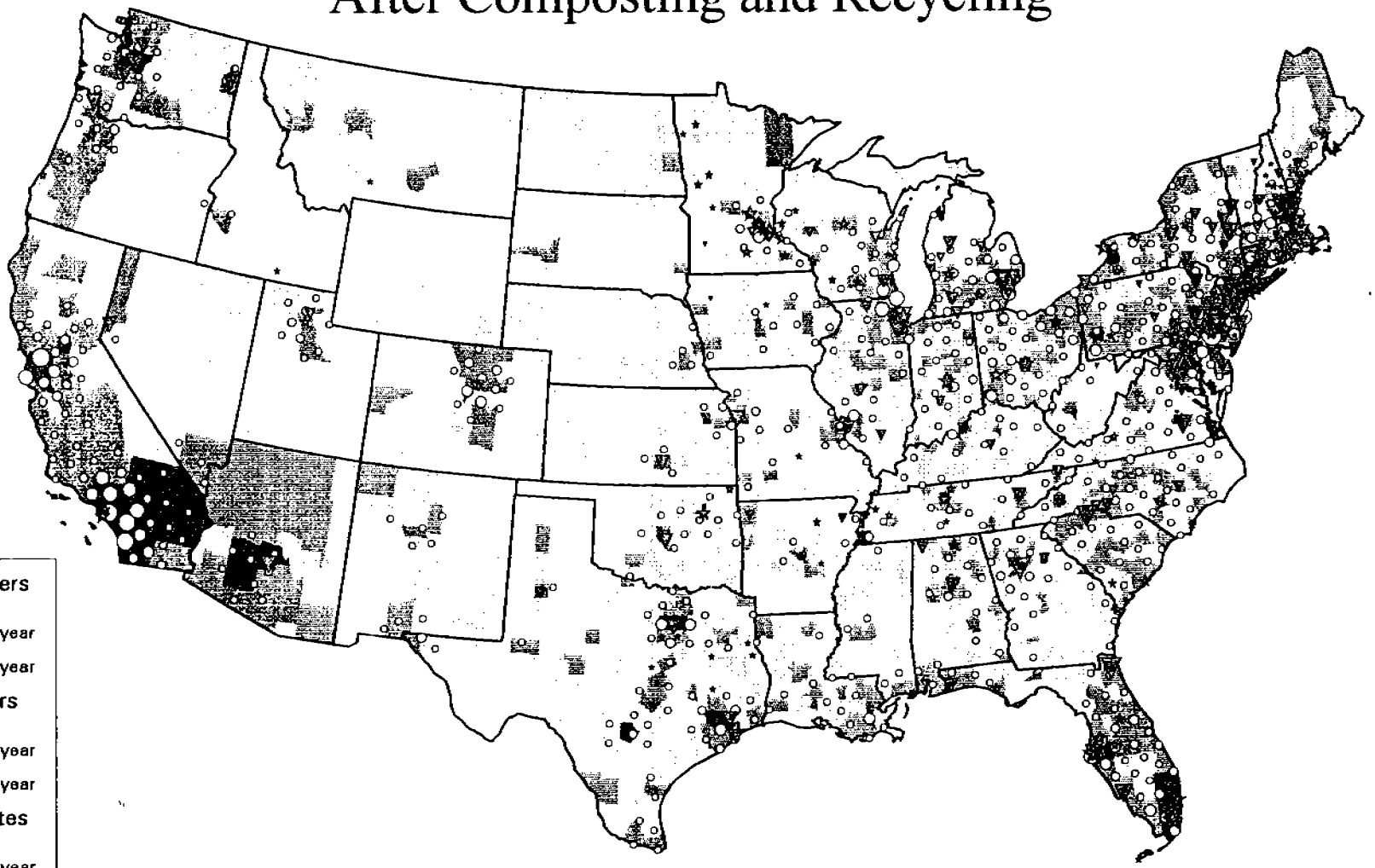
Total New Capacity = 12.843 Million Tons per Year for 7 Plants

Existing and Proposed Combusters and New MSW-Electric Sites
1990 MSW Production per County
After Composting and Recycling



Operational Combusters

- 2000000 tons per year
- 1000 tons per year

Proposed Combusters

- 2000000 tons per year
- 1000 tons per year

New MSW-ElectricSites

- 7000000 tons per year
- 100000 tons per year

MSW Generation
Tons per Year

- more than 500000
- 200000 to 500000
- 100000 to 200000
- 50000 to 100000
- 20000 to 50000
- 1 to 20000

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Total Operational Capacity = 40.281 Million Tons per Year for 182 Plants
Total Proposed/Under Construction Capacity = 47.332 Million Tons per Year for 168 Plants
New Capacity = 164.870 Million Tons per Year for 580 Plants

Table 7. New capacity projections using GIS-enhanced analysis

Scenario	Ethanol		MSW-Electric	
	Number new Facilities (50 mil/gal)	Total new capacity (mil. tons)	Number of new facilities (500 tpd)	Total new capacity (mil. tons)
1990	51	84	504	116
2000 w/ 25 % recycling	20	35	364	79
2000 w/ 50 % recycling	7	13	136	34

The difference between the two scenarios for the year 2000 is obviously the impact of the recycling efficiency and how this affects the supplies of MSW available to eastern MSW combusters. Eastern combusters in 2000 are transporting MSW from considerable distances to remain in operation when recycling efficiencies increase. We did not consider how this could affect financial viability, although the results of this study could be used to support this type of analysis.

In either case, a large proportion of the future MSW combustion potential is located in California where strict air quality regulations and environmental concerns have prevented any significant development of MSW combustion capacity to date (Table 8). If this trend continues, the new capacity in California should be subtracted from the estimates provided in Table 7. California could support 48 sites with a combined capacity of 21.7 million tons of MSW. The adjusted U.S. potential could fall to 57 million tons in 2000 for the 25 percent recycling case and only 12 million tons in the 50 percent recycling case.

This is the type of regional analysis that GIS can support. Several eastern states have enacted or are considering enacting legislation to prevent the construction of future MSW combustion facilities. Had this analysis shown potential sites in these states, we could chose to eliminate them on this basis.

The difference between ethanol and MSW electric potential is the result of the scale of the facilities and feedstock requirements. Because the feedstock requirements for ethanol plants exceeds 4500 tpd in 2000, there are very few sites available. If any MSW combustion facilities are constructed in these areas between 1990 and 2000, fewer sites could be available than indicated here.

Table 8. New MSW Combustion Capacity Potential in Addition to Existing and Planned

State	1990 New Capacity with 17 percent recycling eff.		2000 New Capacity with 25 percent recycling eff.		2000 New Capacity with 50 percent recycling eff.	
	Number of New Sites 500 tpd	Capacity of New Sites	Number of New Sites 500 tpd	Capacity of New Sites	Number of New Sites 500 tpd	Capacity of New Sites
AK	0	0	0	0	0	0
AL	13	1,943,954	11	1,627,358	0	0
AR	3	449,974	5	762,088	1	146,487
AZ	8	1,197,501	6	901,572	1	146,180
CA	50	21,602,573	48	21,652,059	41	16,503,001
CO	12	3,858,605	12	3,577,602	8	2,142,395
CT	2	301,279	0	0	0	0
DC	0	0	0	0	0	0
DE	1	155,963	0	0	0	0
FL	22	4,448,087	2	297,213	0	0
GA	18	3,410,019	14	2,201,606	0	0
HI	0	0	0	0	0	0
IA	7	1,065,397	7	1,089,362	3	448,973
ID	1	151,821	1	153,205	1	146,631
IL	18	4,787,808	19	5,105,420	12	3,000,889
IN	17	3,103,659	16	2,538,000	2	352,889
KS	7	1,360,888	3	602,892	1	148,409
KY	12	1,819,147	10	1,679,451	0	0
LA	13	2,241,000	14	2,635,292	10	1,539,935
MA	4	1,011,121	0	0	0	0
MD	5	845,609	0	0	0	0
ME	2	295,001	0	0	0	0
MI	19	4,748,941	16	2,871,215	2	297,773
MN	5	847,792	0	0	0	0
MO	12	2,170,584	10	1,759,178	4	611,517
MS	8	1,202,471	7	1,082,333	3	460,565
MT	0	0	0	0	0	0
NC	22	3,572,862	14	2,181,368	0	0
ND	0	0	0	0	0	0
NE	4	620,930	3	471,911	2	304,612
NH	2	306,745	0	0	0	0
NJ	5	5,835,760	0	0	0	0
NM	8	1,237,250	7	1,132,293	6	904,816
NV	4	589,575	3	443,907	1	146,876
NY	19	7,362,103	3	467,433	0	0
OH	23	5,382,421	25	5,136,293	0	0
OK	11	1,650,804	5	755,529	1	146,438
OR	7	1,201,591	6	960,906	2	298,812
PA	23	4,674,880	9	1,820,501	0	0
RI	1	173,994	0	0	0	0
SC	12	1,859,315	9	1,335,217	0	0
SD	0	0	0	0	0	0
TN	12	1,836,555	6	892,096	1	147,048
TX	37	7,467,852	38	7,374,720	26	4,299,534
UT	8	1,371,072	7	1,201,301	4	620,772
VA	16	2,593,860	6	911,321	0	0
VT	2	303,699	0	0	0	0
WA	13	2,360,250	8	1,248,793	0	0
WI	9	2,012,914	7	1,119,305	4	836,806
WV	7	1,039,996	7	1,047,201	0	0
WY	0	0	0	0	0	0
Total	504	116,473,620	364	79,035,940	136	33,651,356

However, once again, the majority of these sites are in California and it is unlikely that California will significantly increase their MSW combustion capacity in this time frame (Table 9). Therefore, California may be a promising state to explore the siting of MSW-ethanol plants. This is especially true, since the same air quality regulations that retard MSW combustion capacity encourage the use of oxygenated fuels. California also has regulations requiring the purchase of flexi-fueled vehicles which could be operated on dedicated ethanol fuel supplies.

Similarly, we could show where ethanol incentives could reduce production costs or where tipping fees are high enough to cover sorting costs (and costs of landfilling non-organic materials). Map 19 shows the conjuncture of ethanol sites, production incentives and tipping fees high enough to cover associated costs. We could have used simple cost reduction analysis to demonstrate the impact of these incentives on ethanol production costs. However, these type of analysis could be conducted on a number of tools and does not adequately demonstrate the analytical ability of a GIS in this instance.

Similarly, we could show where regional demand for new electric capacity was projected. We could add information on the avoided costs offered in selected utility areas. These types of information could be used to assess commercial development potential, regional penetration rates, transportation costs, transmission costs, and other issues that have long eluded the analyst. However, without a relational analytic tool (MAPINFO cannot perform relational analysis) the detailed level of analysis suggested here cannot be performed.

However, analysts are aware of these issues and how they might affect the opportunities and barriers to renewable energy development. Without any access to regionally defined data and the tools to manipulate it, we are limited in our abilities to develop sound rationales for regional renewable energy development. This new ability can provide a new level of richness to future CE analysis.

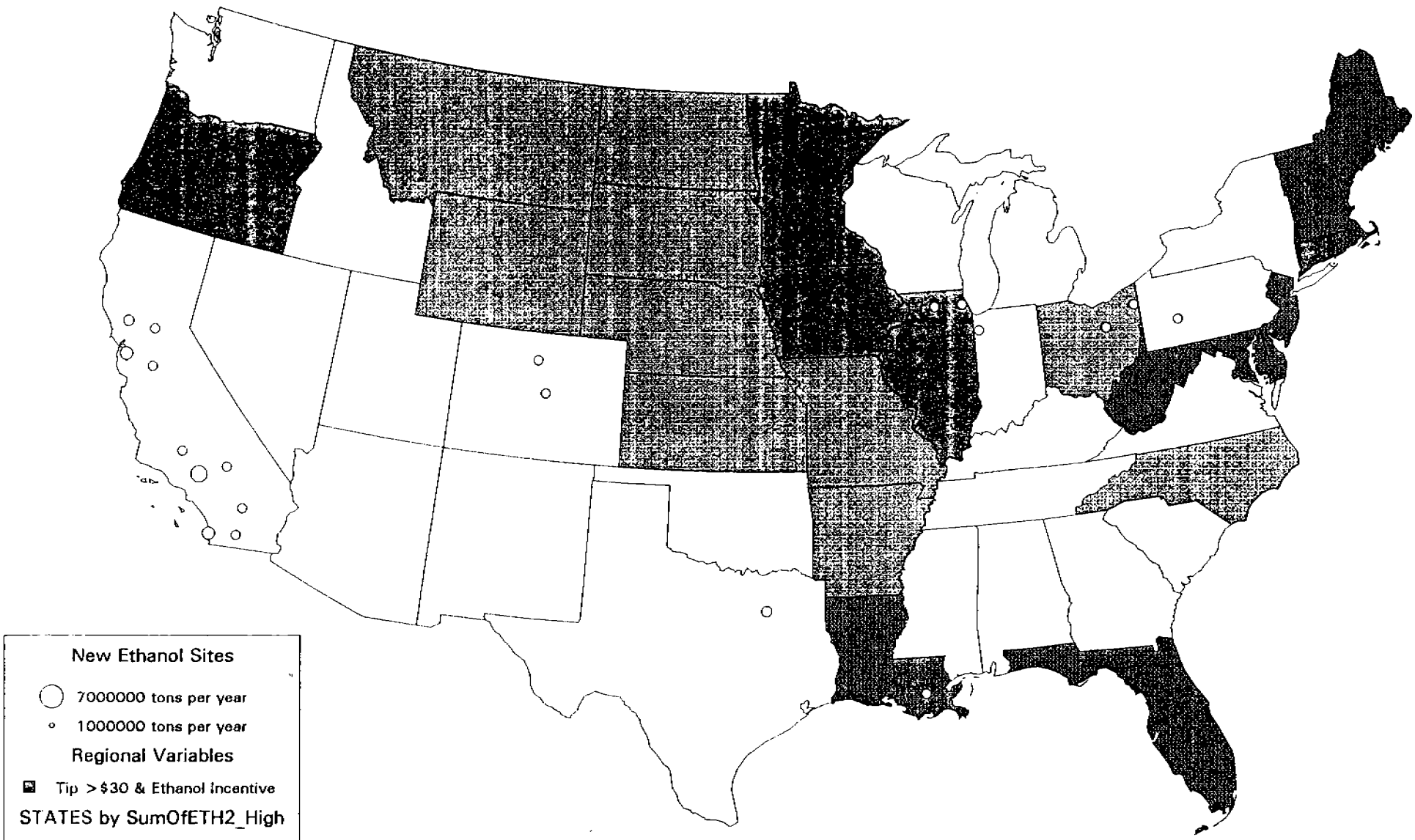
Summary

This report is intended as an exercise to show how GIS can expand the depth of traditional analysis. The ability to consider regional factors, such as state regulations, resource distribution, power demand, regional market prices, and infrastructure provides the analyst with a level of detail that has not be easy to accomodate in the past. This analysis could have continued to examine the effect that multiple factors have on production costs. This was part of the original plan. However, once the information on state-by-state capacity projections had been generated (Table 7), the exercise of applying state ethanol production incentives, tipping fees, and regulatory factors is one that could have been conducted by a number of accounting tools. This is not true of every case that a GIS would be asked to evaluate. The most important ability that GIS provides to the analyst is the ability to conduct relational analysis--such as the generation of potential new sites for energy development.

Table 9. New MSW-Ethanol Capacity Potential

State	1990 New Capacity with 17 percent recycling eff.		2000 New Capacity with 25 percent recycling eff.		2000 New Capacity with 50 percent recycling eff.	
	Number of New Sites 500 tpd	Capacity of New Sites	Number of New Sites 500 tpd	Capacity of New Sites	Number of New Sites 500 tpd	Capacity of New Sites
AK	0	0	0	0	0	0
AL	0	0	0	0	0	0
AR	0	0	0	0	0	0
AZ	0	0	0	0	0	0
CA	14	28,543,830	10	19,238,671	6	11,067,132
CO	2	2,840,532	2	3,107,040	1	1,776,145
CT	2	4,972,698	0	0	0	0
DC	0	0	0	0	0	0
DE	0	0	0	0	0	0
FL	3	4,361,276	0	0	0	0
GA	1	1,385,450	0	0	0	0
HI	0	0	0	0	0	0
IA	0	0	0	0	0	0
ID	0	0	0	0	0	0
IL	2	2,846,167	2	3,123,240	0	0
IN	1	1,421,027	1	1,564,395	0	0
KS	1	1,389,311	0	0	0	0
KY	0	0	0	0	0	0
LA	1	1,390,522	1	1,556,479	0	0
MA	0	0	0	0	0	0
MD	1	1,465,474	0	0	0	0
ME	0	0	0	0	0	0
MI	4	5,648,737	0	0	0	0
MN	0	0	0	0	0	0
MO	1	1,387,267	0	0	0	0
MS	0	0	0	0	0	0
MT	0	0	0	0	0	0
NC	0	0	0	0	0	0
ND	0	0	0	0	0	0
NE	0	0	0	0	0	0
NH	1	1,387,749	0	0	0	0
NJ	1	1,544,713	0	0	0	0
NM	1	1,393,550	0	0	0	0
NV	0	0	0	0	0	0
NY	3	4,205,189	0	0	0	0
OH	4	5,797,453	2	3,117,611	0	0
OK	0	0	0	0	0	0
OR	0	0	0	0	0	0
PA	2	3,056,302	1	1,549,705	0	0
RI	0	0	0	0	0	0
SC	0	0	0	0	0	0
SD	0	0	0	0	0	0
TN	0	0	0	0	0	0
TX	2	2,812,017	1	1,588,519	0	0
UT	0	0	0	0	0	0
VA	1	1,403,942	0	0	0	0
VT	0	0	0	0	0	0
WA	1	1,388,871	0	0	0	0
WI	1	1,458,060	0	0	0	0
WV	1	1,396,480	0	0	0	0
WY	0	0	0	0	0	0
Total	51	83,496,617	20	34,845,660	7	12,843,277

Ethanol Production Incentives with Potential Sites, Year 2000



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MAPINFO is a desktop mapping product with limited GIS abilities. The valuable portion of the analysis conducted in this report--the site locations and capacity--were done using custom programs on a mainframe that simulated the abilities of a GIS system. The results of this off-line analysis were inputs to MAPINFO.

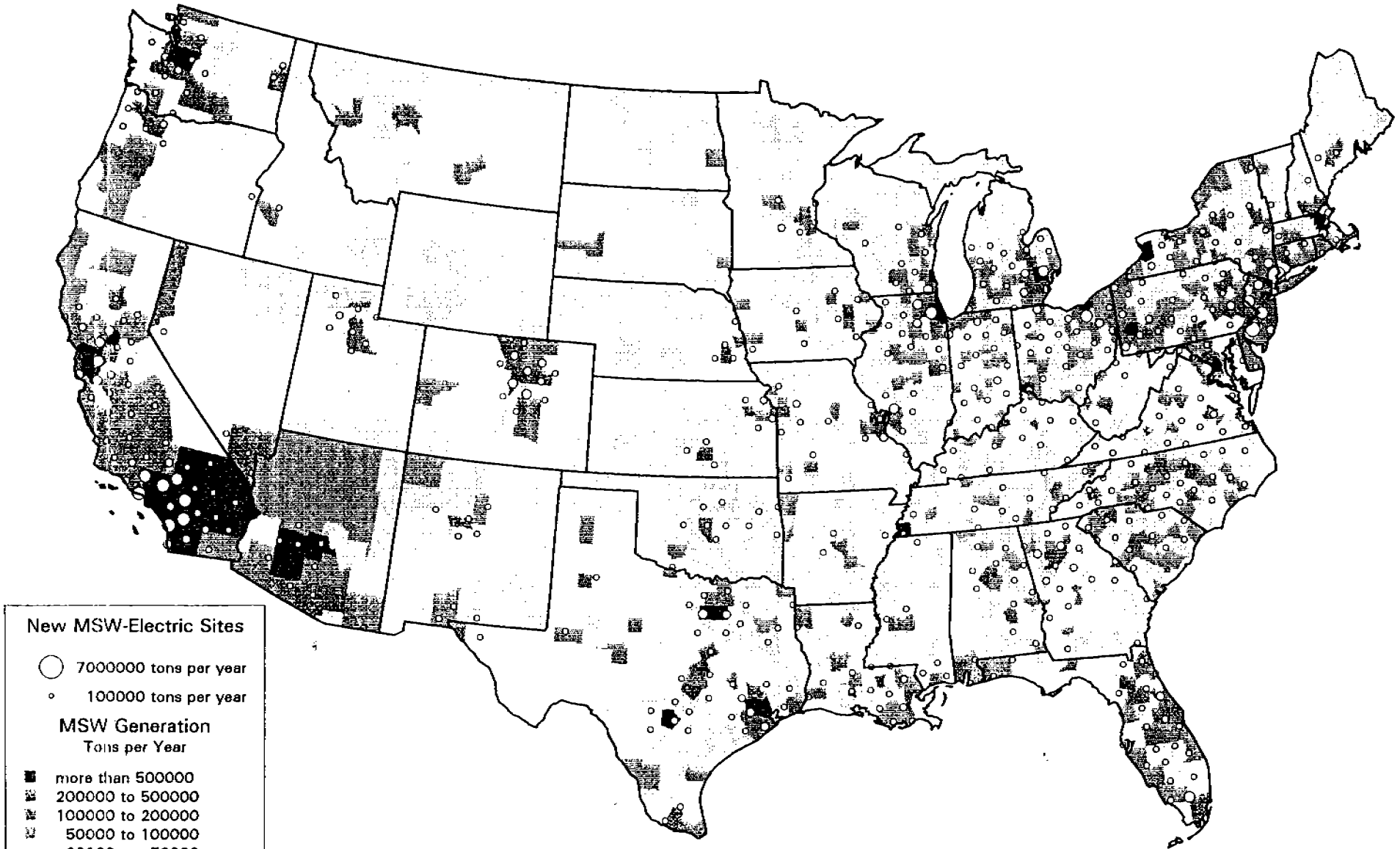
The results of this analysis is a state-by-state breakdown of new sites, local supplies that could be dedicated to those sites, and a roll-up of this information to produce national estimates of future new capacity. This analysis also provided a number of interesting insights concerning the potential opportunities and barriers facing MSW combustion and ethanol production, in addition to insights concerning the MSW market and possible environmental and financial implications of MSW combustion development.

From this analysis we can conclude that if MSW supplies remain static beyond 2000 as a result of waste minimization technologies at the source, recycling, and composting then the increase in future MSW combustion capacity is limited to between 60 and 104 million tons per year; a 50 to 160 percent increase from today's capacity. Similarly, there could be between 7 and 20 sites available in 2000 for biomass-ethanol production if MSW supplies at these sites are unaffected by MSW combustion demand, as is likely for the California sites.

The competitive advantage that MSW combustion has over MSW-ethanol is that it is currently commercial. The number of available sites outside of California could be reduced if any MSW combustion facilities are located at the same sites. The ethanol sites shown in Illinois are especially favorable because these sites also present ethanol production incentives and tipping fees high enough to cover sorting and landfilling costs. In fact, this result was projected in the recent biomass-ethanol fuel cycle report.

The results generated by this study would be difficult to reproduce using other tools. GIS is a tool that will substantially enhance the analytic capabilities of CE in many areas. We believe that OPA and other CE sector offices should seriously consider an investment in a GIS to enrich analysis and further the study of regional characteristics that affect renewable energy development.

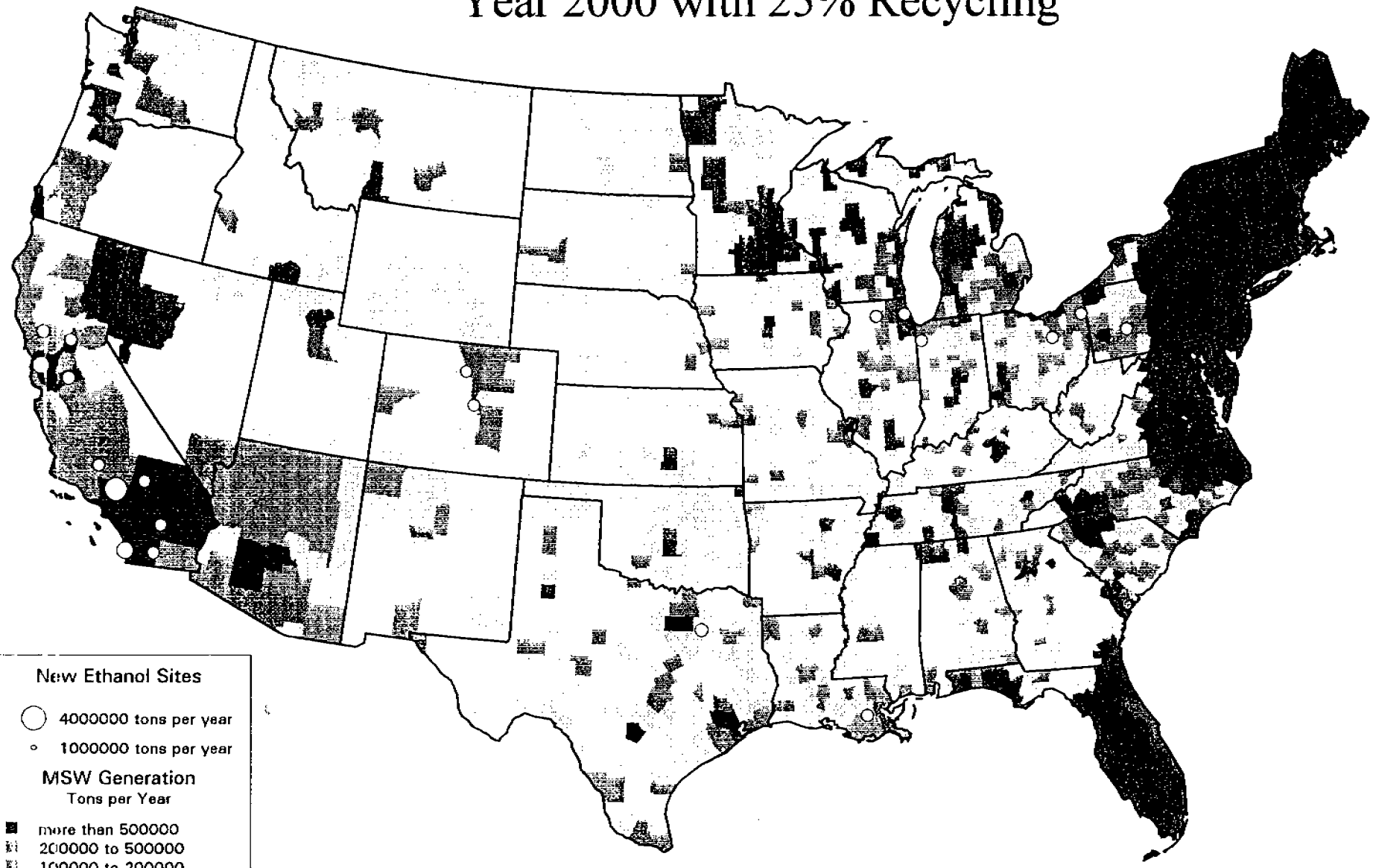
MSW Production per County with New MSW-Electric Sites After Composting, Recycling, and Combustion 1990 Franklin Data



NREL Renewable Energy Resource Information & Analysis Center

Total New Plant Capacity = 116.473 Million Tons per Year for 504 Plants

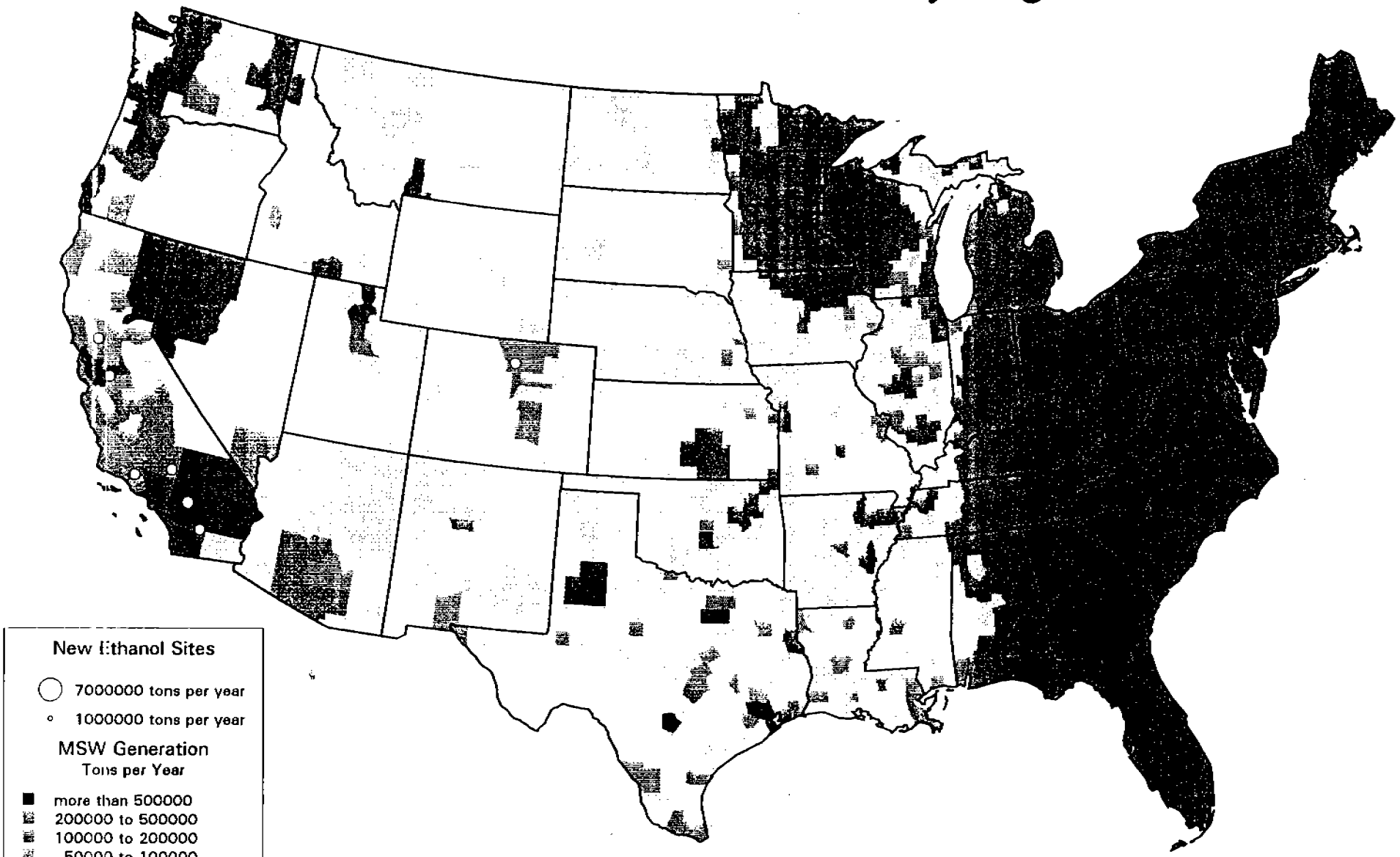
MSW Production per County with New Ethanol Sites After Composting, Recycling, and Combustion Year 2000 with 25% Recycling



Total New Capacity = 34.845 Million Tons per Year for 20 Plants

NREL Renewable Energy Resource Information & Analysis Center

MSW Production per State with New Ethanol Sites After Composting, Recycling, and Combustion Year 2000 with 50% Recycling



NREL Renewable Energy Resource Information & Analysis Center

Total New Capacity = 12.843 Million Tons per Year for 7 Plants